S.I.A.

REPORT

OF THE

FIFTY-THIRD MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

SOUTHPORT IN SEPTEMBER 1883.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
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LIST OF PLATES.

* This plate was presented by the author; the materials for it having been received by him after the article was printed.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and*

all future years the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and thearrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.

1. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him.[1] *Claims under this Rule to be sent to the Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first

[1] Revised by the General Committee, Southampton, 1882.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or

meeting. The Sectional Presidents of former years are *ex officio* members of the Organizing Sectional Committees.[1]

An Organizing Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the General Committee, after which their functions as an Organizing Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly.
3. Papers which have been reported on unfavourably by the Organizing Committees shall not be brought before the Sectional Committees.[5]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis

before.........................., addressed thus—'General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ....' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and Abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Secretary, *before the conclusion of the Meeting.*

[1] Added by the General Committee, Sheffield, 1879.

[2] Revised by the General Committee, Swansea, 1880.

[3] Passed by the General Committee, Edinburgh, 1871.

[4] The meeting on Saturday was made optional by the General Committee at Southport, 1883.

[5] These rules were adopted by the General Committee, Plymouth, 1877.

of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee.[1] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxiii), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they

[1] This and the following sentence were added by the General Committee, 1871.

can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[1]

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next Meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken,[2] and the reading of communications, in the order previously made public, commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

[1] Passed by the General Committee at Sheffield, 1879.

[2] The meeting on Saturday may begin, if desired by the Committee, at any time not earlier than 10 or later than 11. Passed by the General Committee at Southport, 1883.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford. CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

HIS ROYAL HIGHNESS THE PRINCE CONSORT.. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G S Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S... OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. ...... MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge ...... CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. ...... NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S. F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.

1883.

PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex The Duke of Norfolk The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Professor Phillips, D.C.L., F.R.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Sir John Hawkshaw, F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.

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PRESIDENTS.	VICE-PRESIDENTS.	SECRETARIES.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S. L. & E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology. SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.I.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.

Presidents and Secretaries of the Sections of the Association.

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

Date and Place	Presidents	Secretaries
1832. Oxford	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries
1835. Dublin	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S.	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow	Prof. Forbes, F.R.S.	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
1844. York	The Earl of Rosse, F.R.S.	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S.	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol......	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. McAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. McAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Prof. O. J. Lodge, D. McAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. McAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.,	W. M. Hicks, Prof. O. J. Lodge, D. McAlister, Prof. R. C. Rowe.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

Date and Place	Presidents	Secretaries
1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope........................	Mr. Johnston, Dr Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.

Date and Place	Presidents	Secretaries
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	H. B. Dixon, Dr. W. R. Eaton Hodgkinson, P. Phillips Bedson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.

Date and Place	Presidents	Secretaries
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section," for Presidents and Secretaries of which see page xliv.

Date and Place	Presidents	Secretaries
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart. K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S............	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham.....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xliii.

Date and Place	Presidents	Secretaries
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D........	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see pp. xliii, xliv.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

Date and Place	Presidents	Secretaries
1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S.—*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S.—*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, M.A., F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, M.A., F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport [1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M Marshall, Howard Saunders, Dr. G. A. Woods.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard......................	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844 York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

[1] By direction of the General Committee at Southampton (1882) the Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

SECTION E.—PHYSIOLOGY.

Date and Place	Presidents	Secretaries
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D................	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxxviii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard......................	Dr. King.
1847. Oxford......	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Çull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. xli). The Section being then vacant was assigned in 1851 to Geography.

[2] *Vide* note on page xlii.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, Clements R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

Date and Place	Presidents	Secretaries
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton ...	Francis Galton, F.R.S.........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S.L.&E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

Date and Place	Presidents	Secretaries
1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841 Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.

Date and Place	Presidents	Secretaries
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne. F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, Frank P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres.S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.......	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.

Date and Place	Presidents	Secretaries
1846. Southampton.	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford......	Rev. Professor Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Professor Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S..........	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S..........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.

Date and Place	Presidents	Secretaries
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton.	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.
1883. Southport	James Brunlees, F.R.S.E., Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.

List of Evening Lectures.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson......................	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.

Date and Place	Lecturer	Subject of Discourse
1853. Hull.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.............	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S.............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S..........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S. ...	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S..........	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S....	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S................	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.

Date and Place	Lecturer	Subject of Discourse
1872. Brighton ... (*cont.*)	Prof. W. K. Clifford............	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarized Light.
	F. J. Bramwell, F.R.S.........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.............	The new Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S.	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.,	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick, F.R.S.E.	Galvani and Animal Electricity.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877 Plymouth...	W. H. Preece.....................	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York.........	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L. Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S.	Talking by Electricity—Telephones.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE SOUTHPORT MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Professor Henrici, Ph.D., F.R.S., President of the London Mathematical Society.

Vice-Presidents.—Professor J. C. Adams, F.R.S.; Professor R. S. Ball, F.R.S.; J. Baxendell, F.R.A.S.; J. W. L. Glaisher, F.R.S.; Rev. Professor Salmon, D.D., F.R.S.; Sir William Siemens, F.R.S.; Professor Balfour Stewart, F.R.S.; Professor Stokes, Sec. R.S.; G. Johnstone Stoney, F.R.S.; Sir W. Thomson, F.R.S.

Secretaries.—W. M. Hicks, M.A.; Professor O. J. Lodge; D. MacAlister, M.A. (*Recorder*); Professor R. C. Rowe.

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Secretaries.—Professor P. P. Bedson, D.Sc. (*Recorder*); H. B. Dixon, M.A.; H. Forster Morley, D.Sc.

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Secretaries.—R. Betley, F.G.S.; C. E. De Rance, F.G.S.; W. Topley, F.G.S. (*Recorder*); W. Whitaker, F.G.S.

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SECTION E.—GEOGRAPHY.

President.—Lieut.-Colonel H. H. Godwin-Austen, F.R.S., F.R.G.S.

Vice-Presidents.—Sir Rawson W. Rawson, K.C.M.G., C.B.; Rev. Canon Tristram, D.D., F.R.S.

Secretaries.—John Coles, F.R.G.S.; E. G. Ravenstein, F.R.G.S; E. C. Rye, F.Z.S. (*Recorder*).

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President.—R. H. Inglis Palgrave, F.R.S., F.S.S.

Vice-Presidents.—Professor R. Adamson, M.A., LL.D.; J. Heywood, F.R.S.

Secretaries.—Rev. W. Cunningham, M.A; Professor H. S. Foxwell, F.S.S.; J. N. Keynes, F.S.S.; Constantine Molloy (*Recorder*).

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President.—James Brunlees, F.R.S.E., Pres.Inst.C.E.

Vice-Presidents.—W. H. Barlow, F.R.S.; J. F. Bateman, F.R.S.; Sir F. J. Bramwell, F.R.S.; Professor Osborne Reynolds, F.R.S.; Sir William Siemens, F.R.S.; Sir Joseph Whitworth, F.R.S.

Secretaries.—A. T. Atchison, M.A.; Edward Rigg, M.A.; H. Trueman Wood, B.A. (*Recorder*).

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham..........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ...	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds..................	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ..	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.......	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23 ...	Southampton	Dr. C. W. Siemens, F.R.S.......	178	17
1883, Sept. 19 ...	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	£20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 3 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883

* Ladies were not admitted by purchased Tickets until 1843.
† Tickets of Admission to Sections only. ‡ Including Ladies.

THE GENERAL TREASURER'S ACCOUNT from August 23, 1882 (commencement of Southampton Meeting), to September 19, 1883. (Not including receipts at Southport Meeting.)

1882–83.	RECEIPTS.	£	s.	d.
Aug. 23.	By Balance brought forward	425	3	7
	„ Life Compositions at Southampton Meeting and since	490	0	0
	„ Annual Subscriptions ditto ditto	454	0	0
	„ New Annual Members ditto ditto	312	0	0
	„ Associates' Tickets sold at Southampton Meeting	515	0	0
	„ Ladies' Tickets ditto	189	0	0
	„ Dividends on Stock................................	248	1	11
	„ Sale of Publications	122	2	9
1883.	„ Rent, &c., received from London Mathematical Society, year ending Michaelmas, 1882..	12	15	0
May 29. 1882.	Received from Sir Joseph Hooker unexpended grant made at Southampton Meeting for Exploration of Mt. Kilimanjaro, E. Africa ...	500	0	0
Aug. 24.	Unexpended Balance of grant made at York Meeting for Exploration of Caves in Ireland	8	0	0
1882. October. 1883.	Unexpended Balance of grant made at York Meeting for photographing Ultra-violet Spark Spectra	1	0	0
Sept. 15.	Received from Lt.-Col. Godwin Austen unexpended balance of grant made for Exploration of Socotra	145	0	0
		£3422	3	3

1882–83.	PAYMENTS.	£	s.	d.	£	s.	d.
	By payment of Expenses of Southampton Meeting, also sundry Printing, Binding, Advertising, and Incidental Expenses				236	15	4
	„ Messrs. Spottiswoode & Co.'s account for printing—1882–83—Report of 52nd Meeting, Vol. LI.				687	2	9
	„ Salaries (1 year)				497	10	0
	„ Rent of Office (22 Albemarle Street—1 year)............				117	0	0
	„ Grants made at Southampton Meeting:—						
1882. Oct. 11.	Natural History of Timor-laut	50	0	0			
„ 20.	British Fossil Polyzoa	10	0	0			
„ 23.	Circulation of Underground Waters ..	15	0	0			
„ 23.	Zoological Literature Record	100	0	0			
„ 31.	Exploration of Mt. Kilimanjaro, E. Africa	500	0	0			
Nov. 3.	Erosion of Sea-coast of England and Wales...........................	10	0	0			
„ 22.	Fossil Plants of Halifax	20	0	0			
Dec. 5.	Elimination of Nitrogen by Bodily Exercise						
May 29.	Ditto ditto ditto	38	3	3			
July 16.	Ditto ditto ditto						
Dec. 12.	Isomeric Naphthalene Derivatives....	15	0	0			
„ 27.	Zoological Station at Naples	80	0	0			
1883. Jan. 13.	Investigation of Loughton Camp....	10	0	0			
Feb. 16.	Earthquake Phenomena of Japan	50	0	0			
April 16.	Meteorological Observations on Ben Nevis..............................	50	0	0			
May 29.	Fossil Phyllopoda of Palæozoic Rocks	25	0	0			
July 2.	Migration of Birds	20	0	0			
„ 12.	Geological Record	50	0	0			
Aug. 2.	Exploration of Caves in South of Ireland	10	0	0			
„ 17.	Scottish Zoological Station	25	0	0			
Sept. 5.	Screw Gauges	5	0	0			
1883.					1083	3	3
Sept. 19.	Balance at Bank of England, Western Branch	£637	9	10			
„	In local bank at Southport	163	2	1			
					800	11	11
					£3422	3	3

ALEX. W. WILLIAMSON.

Examined and found correct.

JOHN EVANS,
G. CAREY FOSTER, } Auditors.

OFFICERS AND COUNCIL, 1883-84.

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F. WOLFERSTAN THOMAS, Esq.

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Professor T. G. BONNEY, D.Sc., F.R.S., F.S.A., Pres.G.S., 22 Albemarle Street, London, W.

GENERAL TREASURER.

Professor A. W. WILLIAMSON, Ph.D., LL.D., F.R.S., F.C.S., University College, London, W.C.

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The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

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REPORT OF THE COUNCIL.

Report of the Council for the year 1882–83, *presented to the General Committee at Southport, on Wednesday, September* 19, 1883.

The Council have received reports during the past year from the General Treasurer, and his account for the year will be laid before the General Committee this day.

Since the meeting at Southampton the following have been elected Corresponding Members of the Association:—

Baumhauer, Dr. E. H.	Langley, Professor
Clausius, Dr. R.	Rath, Professor G. vom
Du Bois-Raymond, Professor	

The Council have nominated Principal J. W. Dawson, C.M.G., LL.D., F.R.S., to be a Vice-President for the meeting at Southport.

As the lamented death of Professor F. M. Balfour, one of the General Secretaries, occurred only a few weeks before the meeting at Southampton, the Council were not prepared at that date to recommend his successor, but at their next meeting they nominated Mr. A. G. Vernon Harcourt, F.R.S., as a General Secretary, and requested him to act in that capacity until the next meeting of the Association. They accordingly now recommend that he be appointed a General Secretary in the room of the late Professor F. M. Balfour.

They regret the loss by death of three of their number. Of these the first was Professor H. J. S. Smith, who at Southampton was elected one of the Vice-Presidents for this meeting; a man of whom it is difficult to say whether he was more regarded with admiration for his rare talents, or beloved for his personal qualities. The Association was deprived, almost simultaneously, of two of its Trustees; both former General Officers; both past Presidents. The very advanced age of General Sabine had for several years prevented him from taking any active part in the business of the Association (though in his time he had been one of its most energetic and laborious members), but in Mr. William Spottiswoode, President of the Royal Society, the Council and the whole Association have lost one who was ever active in promoting its interests, to whom, it was hoped, no small period yet remained for good and useful work. Few men have been so deeply and deservedly lamented, for in him were united, to an exceptional degree, great mental powers, singular ability in practical matters, and a noble unselfishness. The Council recommend that in the place of the late General Sabine and the late Mr. Spottiswoode, Lord Rayleigh and Sir Lyon Playfair be elected Trustees of the Association.

Four resolutions were referred by the General Committee to the Council for consideration, and action, if desirable. In respect of one of these, that which empowered the Council to communicate with Foreign Scientific Associations with the view of promoting the organisation of an

International Scientific Congress, the Council, having regard to the special circumstances of the present and coming year, have deemed it wiser to postpone any decisive action for the present.

In accordance with the powers granted to them by the General Committee in the other resolutions: The Council have considered the question of amalgamating the Departments of Zoology and Botany and of Anatomy and Physiology for the present year, and have decided to amalgamate them under the designation of the Section of Biology, retaining the Department of Anthropology.

The Council have also appointed a Committee, with Mr. F. Galton as Chairman, and Mr. H. G. Fordham as Secretary, 'to draw up suggestions upon methods of more systematic observation and plans of operation for local Societies, together with a more uniform mode of publication of the results of their work.' This Committee were also requested to draw up a list of local Societies which published their transactions. They have presented a preliminary report to the Council, with a request that it may be communicated to the Committees of Sections for consideration and suggestions. This the Council propose to do, and recommend that after it assumes its final form it be printed in the annual volume, among the reports made to the Association. A list of publishing local Societies will be appended to the report.

The Council have further appointed a Committee to co-operate with them for the purpose of considering the arrangements for the meeting at Montreal.

In respect of this meeting, the Council have to inform the Association that of those who were members at the time of the meeting at Southampton, 445 have notified their intention of being present at the meeting at Montreal, and 55 persons have either become members or expressed their wish to become members, with the view of taking part in this meeting. Negotiations with respect to the arrangements for the meeting on the basis of the letter from Sir A. T. Galt, dated March 3, 1883, are still proceeding, and for some little time it will not be possible for the Council to communicate the precise details to the members of the Association, but the following points may be regarded as settled: There will be a reduction of fares on the part of the Steamship Companies to all members of the Association, and a further reduction, in consequence of the Canadian subsidy, at any rate to all who were members at the meeting of 1882; and there will be an excursion after the meeting—free of cost to members as regards transit—one to the Rocky Mountains, lasting from twelve to fourteen days, another to the Falls of Niagara and Chicago; with probably one or two shorter excursions. As soon as all details can be arranged the Council will communicate them to the members of the Association.

The Council have considered what alterations, if any, it may be desirable to make in the transaction of business at the Montreal Meeting, in consequence of the exceptional distance, and the unprecedented fact that the place of meeting is not within the British Isles. They are of opinion that, as there is likely to be so representative a gathering of British members at Montreal, and as 154 members of the General Committee have signified their intention of being present, little alteration will be necessary in the custom, and no changes need be proposed in the written law of the Association. There will, however, be difficulties in fixing the place of meeting for 1886, and the date of that in 1885, for

delegates from the towns concerned could not be expected to attend. It may also be felt that members who are unable to leave the United Kingdom ought to have the opportunity of voting on these points, and on the election of the President and Officers for 1885. The Council, therefore, recommend that the General Committee hold only two meetings at Montreal, and an adjourned meeting at some convenient place in London, on some day, to be hereafter fixed, towards the end of the month of October, 1884.

It has been represented to the Council that a strong wish is felt in some of the Sections to meet at an earlier hour than eleven o'clock on the Saturday morning; the Council, therefore, recommend that an explanatory note be added to the rule which fixes the hour of the Sectional Meetings, to state that on this day only the Committee of any Section can arrange for that Section to commence its meeting at any time not earlier than ten or later than eleven o'clock.

The Council have been informed that, through an inadvertence, the resolution of the Sectional Committee recommending the reappointment of the Committee on Underground Temperature was not transmitted to the Committee of Recommendations, and so did not receive the sanction of the General Committee. The Council, having regard to the important work carried on by that Committee, have requested them, through their Secretary, Professor Everett, to continue their labours and make a report, as though they had been duly appointed. The Council ask that this action of theirs be sanctioned, and that the above-named report be received and printed in the annual volume among the Reports of Committees duly appointed.

One vacancy having been caused in the Council by the death of Professor H. J. S. Smith, one by the retirement of Sir H. E. L. Thuillier, one by the election of Professor Cayley to the Presidency, and one by that of Mr. Vernon Harcourt to the office of General Secretary, there remains only one name which it is necessary to remove from the list.

The Council propose that, in accordance with the regulations, the retiring member shall be the following:—

Mr. J. Heywood.

The Council recommend the re-election of the other ordinary members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Adams, Professor W. G., F.R.S.
Bateman, J. F., Esq., F.R.S.
*Bramwell, Sir F. J., F.R.S.
Darwin, F., Esq., F.R.S.
Dawkins, Professor W. Boyd, F.R.S.
De La Rue, Warren, Esq., F.R.S.
*Dewar, Professor J., F.R.S.
Evans, Captain Sir F. J., K.C.B., F.R.S.
Flower, Professor W. H., F.R.S.
*Gladstone, Dr. J. H., F.R.S.
Glaisher, J. W. L., Esq., F.R.S.
*Godwin-Austen, Lieut.-Col. H. H., F.R.S.
Hastings, G. W., Esq., M.P.
Hawkshaw, J. Clarke, Esq., F.G.S.
*Henrici, Professor O., F.R.S.
Huggins, W., Esq., F.R.S.
Hughes, Professor T. McK., F.G.S.
Jeffreys, Dr. J. Gwyn, F.R.S.
Pengelly, W., Esq., F.R.S.
Perkin, W. H., Esq., F.R.S.
Prestwich, Professor, F.R.S.
Rayleigh, Lord, F.R.S.
Sanderson, Professor J. S. Burdon, F.R.S.
*Sclater-Booth, The Right Hon. G., F.R.S.
Sorby, Dr. H. C., F.R.S.

Recommendations adopted by the General Committee at the Southport Meeting in September 1883.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That Professor Crum Brown, Mr. Milne-Home, Mr. John Murray, and Mr. Buchan be reappointed a Committee for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations on Ben Nevis; that Professor Crum Brown be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor G. Carey Foster, Sir William Thomson, Professor Ayrton, Professor J. Perry, Professor W. G. Adams, Lord Rayleigh, Professor Jenkin, Dr. O. J. Lodge, Dr. John Hopkinson, Dr. A. Muirhead, Mr. W. H. Preece, Mr. Herbert Taylor, Professor Everett, Professor Schuster, Sir W. Siemens, Dr. J. A. Fleming, Professor G. F. Fitzgerald, Mr. R. T. Glazebrook, Professor Chrystal, Mr. H. Tomlinson, and Professor W. Garnett be reappointed a Committee for the purpose of constructing and issuing practical Standards for use in Electrical Measurements; that Mr. Glazebrook be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor Schuster, Sir William Thomson, Professor H. E. Roscoe, Professor A. S. Herschel, Captain W. de W. Abney, Mr. R. H. Scott, and Dr. J. H. Gladstone be reappointed a Committee for the purpose of investigating the practicability of collecting and identifying Meteoric Dust, and of considering the question of undertaking regular observations in various localities; that Professor Schuster be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Captain Abney, Professor W. G. Adams, Professor G. C. Foster, Lord Rayleigh, Mr. Preece, Professor Schuster, Professor Dewar, Mr. A. Vernon Harcourt, and Professor Ayrton be reappointed a Committee for the purpose of fixing a Standard of White Light; that Captain Abney be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Mr. Robert H. Scott, Mr. J. Norman Lockyer, Professor G. G. Stokes, Professor Balfour Stewart, and Mr. G. J. Symons be reappointed a Committee for the purpose of co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861; that Mr. R. H. Scott be the Secretary, and that the still unexpended sum of 50*l.* be again placed at their disposal for the purpose.

That Professor Balfour Stewart, Mr. Knox Laughton, Mr. G. J. Symons, Mr. R. H. Scott, and Mr. Johnstone Stoney be a Committee

for the purpose of co-operating with Mr. E. J. Lowe in his project of establishing a Meteorological Observatory near Chepstow on a permanent and scientific basis, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Mr. James N. Shoolbred and Sir William Thomson be a Committee for the purpose of reducing and tabulating the Tidal Observations in the English Channel made with the Dover Tide-gauge, and of connecting them with observations made on the French coast; that Mr. Shoolbred be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor G. H. Darwin and Professor J. C. Adams be a Committee for the Harmonic Analysis of Tidal Observations; that Professor Darwin be the Secretary, and that the sum of 45*l.* be placed at their disposal for the purpose.

That Professors Odling, Huntington, Dewar, Liveing, Schuster, and Hartley be a Committee for the purpose of investigating by means of Photography the Ultra-violet Spark-spectra emitted by Metallic Elements, and their combinations under varying conditions; that Professor W. N. Hartley be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Mr. R. Etheridge, Mr. T. Gray, and Professor J. Milne be reappointed a Committee for the purpose of investigating the Earthquake Phenomena of Japan; that Professor J. Milne be the Secretary, and that the sum of 75*l.* be placed at their disposal for the purpose.

That Professor W. C. Williamson, Mr. T. Hick, and Mr. W. Cash be reappointed a Committee for the purpose of investigating the Fossil Plants of Halifax; that Mr. W. Cash be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Dr. H. C. Sorby and Mr. G. R. Vine be reappointed a Committee for the purpose of reporting on the British Fossil Polyzoa; that Mr. G. R. Vine be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professors J. Prestwich, W. Boyd Dawkins, T. McK. Hughes, and T. G. Bonney, Dr. H. W. Crosskey, Dr. Deane, and Messrs. C. E. De Rance, H. G. Fordham, J. E. Lee, D. Mackintosh, W. Pengelly, J. Plant, and R. H. Tiddeman be reappointed a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; that Dr. Crosskey be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Mr. R. Etheridge, Dr. H. Woodward, and Professor T. R. Jones be reappointed a Committee for the purpose of reporting on the Fossil Phyllopoda of the Palæozoic Rocks; that Professor T. R. Jones be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professor E. Hull, Dr. H. W. Crosskey, Captain Douglas Galton, Professors J. Prestwich and G. A. Lebour, and Messrs. James Glaisher, E. B. Marten, G. H. Morton, James Parker, W. Pengelly, James Plant, I. Roberts, Fox Strangways, T. S. Stooke, G. J. Symons, W. Topley, Tylden-Wright, E. Wethered, W. Whitaker, and C. E. De Rance be a Committee for the purpose of investigating the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and

Quantity of the Waters supplied to various towns and districts from these formations; that Mr. De Rance be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Dr. J. Evans, Professor W. J. Sollas, and Messrs. W. Carruthers, F. Drew, R. B. Newton, F. W. Rudler, W. Topley, E. Wethered, and W. Whitaker be reappointed a Committee for the purpose of carrying on the Geological Record; that Mr. W. Whitaker be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professor A. H. Green, Professor L. Miall, Mr. John Brigg, and Mr. J. W. Davis be reappointed a Committee for the purpose of assisting in the Exploration of Raygill Fissure, Lothersdale; that Mr. J. W. Davis be the Secretary, and that the sum of 15*l.* be placed at their disposal for the purpose.

That Professor J. Prestwich, Professor T. McK. Hughes, and Mr. W. Topley be reappointed a Committee for the purpose of assisting in the preparation of an International Geological Map of Europe; that Mr. Topley be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Professors Newton, Ray Lankester, and Gamgee be a Committee for the purpose of preparing a Bibliography of certain Groups of Invertebrata; that Professor Newton be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Mr. Sclater, Mr. Howard Saunders, and Mr. Thiselton Dyer be reappointed a Committee for the purpose of investigating the Natural History of Timor-laut; that Mr. Thiselton Dyer be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor Ray Lankester, Mr. P. L. Sclater, Professor M. Foster, Mr. A. Sedgwick, Professor A. M. Marshall, Professor A. C. Haddon, and Mr. Percy Sladen be reappointed a Committee for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples; that Mr. Percy Sladen be the Secretary, and that the sum of 80*l.* be placed at their disposal for the purpose.

That Mr. J. Park Harrison, General Pitt-Rivers, Professor Flower, Professor Thane, Dr. Beddoe, Mr. Brabrook, Dr. Muirhead, Mr. F. W. Rudler, and Dr. Garson, be a Committee for the purpose of defining the Facial Characteristics of the Races and Principal Crosses in the British Isles, and obtaining illustrative Photographs with a view to their publication; that Dr. Garson be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Sir J. Hooker, Dr. Günther, Mr. Howard Saunders, and Mr. Sclater be reappointed a Committee for the purpose of exploring Kilimanjaro and the adjoining mountains of Equatorial Africa; that Mr. Sclater be the Secretary, and that the sum of 500*l.* be placed at their disposal for the purpose.

That Mr. J. Cordeaux, Mr. J. A. Harvie Brown, Professor Newton, Mr. R. M. Barrington, Mr. A. G. More, and Mr. W. Eagle Clarke be reappointed a Committee for the purpose of obtaining (with the consent of the Master and Elder Brethren of the Trinity House and of the Commissioners of Northern Lights) observations on the Migration of Birds at Lighthouses and Lightships, and of reporting upon the same at the meeting of 1884; that Mr. Cordeaux be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Professor M. Foster, Dr. Pye-Smith, and Dr. L. C. Wooldridge

be a Committee for the purpose of prosecuting a research on the Coagulation of the Blood; that Dr. L. C. Wooldridge be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Mr. Stainton, Sir John Lubbock, and Mr. E. C. Rye be reappointed a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Lieut.-Colonel Godwin-Austen, Mr. W. T. Blanford, Lord Alfred Churchill, Mr. Francis Galton, Professor Moseley, Admiral Sir Erasmus Ommanney, and Mr. H. W. Bates be a Committee for the purpose of considering the most expedient methods of furthering the Exploration of New Guinea, and of advising the Council thereon; that the Council be empowered to make representations, if they see fit, to the Imperial and to any Colonial Government, and to any Public Institution or Scientific Society, urging the exploration of New Guinea, and to offer a grant in aid of their scientific outfit; that Mr. H. W. Bates be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Mr. Brabrook, Mr. F. Galton, Sir Rawson Rawson, and Mr. C. Roberts be reappointed a Committee for the purpose of defraying the expenses of completing the preparation of the Final Report of the Anthropometric Committee; that Mr. Brabrook be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Sir Frederick Bramwell, Professor A. W. Williamson, Professor Sir William Thomson, Mr. St. John Vincent Day, Sir W. Siemens, Sir F. Abel, Captain Douglas Galton, Mr. E. H. Carbutt, Mr. Macrory, Mr. H. Trueman Wood, Mr. W. H. Barlow, Mr. A. T. Atchison, Mr. R. E. Webster, Mr. A. Carpmael, Sir John Lubbock, Mr. Theodore Aston, and Mr. James Brunlees be reappointed a Committee for the purpose of watching and reporting to the Council on Patent Legislation; that Sir Frederick Bramwell be the Secretary, and that the sum of 5*l.* be placed at their disposal for the purpose.

Not involving Grants of Money.

That the Committee, consisting of Mr. Francis Galton (Chairman), Dr. Crosskey, Mr. C. E. De Rance, Mr. H. G. Fordham (Secretary), Mr. John Hopkinson, Mr. R. Meldola, Mr. A. Ramsay, Professor Sollas, Mr. G. J. Symons, and Mr. W. Whitaker, appointed by the Council in compliance with a resolution of the General Committee at Southampton, relating to Local Scientific Societies, be reappointed.

That Professor Cayley, Professor Stokes, Sir William Thomson, Mr. James Glaisher, and Mr. J. W. L. Glaisher be reappointed a Committee on Mathematical Tables; and that Mr. J. W. L. Glaisher be the Secretary.

That Professor Sylvester, Professor Cayley, and Professor Salmon be reappointed a Committee for the purpose of Calculating Tables of the Fundamental Invariants of Algebraic Forms; and that Professor Sylvester be the Secretary.

That Professor Balfour Stewart, Professor Stokes, Mr. G. Johnstone Stoney, Professor Roscoe, Professor Schuster, Captain Abney, and Mr. G. J. Symons be a Committee for the purpose of considering the best methods of recording the direct intensity of Solar Radiation; and that Professor Balfour Stewart be the Secretary.

That Professor Everett, Professor Sir William Thomson, Mr. G. J.

Symons, Sir A. C. Ramsay, Dr. A. Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Prestwich, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, and Mr. A. Strahan be reappointed a Committee for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water; and that Professor Everett be the Secretary.

That Professor Sir William Thomson, Sir W. Siemens, Mr. W. H. Barlow, Professor A. W. Williamson, Mr. W. H. Preece, and Mr. J. M. Thomson be a Committee for the purpose of promoting arrangements for facilitating the use of Weights and Measures in accordance with the permissive clauses of the Weights and Measures Act, 1878; and that Mr. J. M. Thomson be the Secretary.

That Professors Williamson, Dewar, Frankland, Roscoe, Crum Brown, Odling, and Armstrong, Messrs. A. G. Vernon Harcourt, J. Millar Thomson, H. B. Dixon, and V. H. Veley, and Drs. F. Japp and H. Forster Morley be a Committee for the purpose of drawing up a statement of the varieties of Chemical Names which have come into use, for indicating the causes which have led to their adoption, and for considering what can be done to bring about some convergence of the views on Chemical Nomenclature obtaining among English and foreign chemists; and that Mr. H. B. Dixon be the Secretary.

That Captain Abney, Professor Stokes, and Professor Schuster, with the addition of the names of Mr. Lockyer and Dr. Huggins, be reappointed a Committee for the purpose of determining the best experimental methods that can be used in observing Total Solar Eclipses; and that Professor Schuster be the Secretary.

That Professors W. A. Tilden and H. E. Armstrong be a Committee for the purpose of investigating Isomeric Naphthaline Derivatives; and that Professor H. E. Armstrong be the Secretary.

That Professors Dewar and A. W. Williamson, Dr. Marshall Watts, Captain Abney, Dr. Stoney, and Professors W. N. Hartley, McLeod, Carey Foster, A. K. Huntington, Emerson Reynolds, Reinold, Liveing, Lord Rayleigh, and W. Chandler Roberts be a Committee for the purpose of reporting upon the present state of our knowledge of Spectrum Analysis; and that Professor W. Chandler Roberts be the Secretary.

That Professor Roscoe, Mr. Lockyer, Professors Dewar, Liveing, Schuster, and W. N. Hartley, Captain Abney, and Dr. Marshall Watts be a Committee for the purpose of preparing a new series of Wave-lengths Tables of the Spectra of the Elements; and that Dr. Marshall Watts be the Secretary.

That Messrs. R. B. Grantham, J. B. Redman, J. W. Woodall, W. Whitaker, W. Topley, and C. E. De Rance be reappointed a Committee for the purpose of inquiring into the rate of Erosion of the Sea-coasts of England and Wales, and the influence of the artificial abstraction of shingle and other material in that action; and that Messrs. Topley and De Rance be the Secretaries.

That Dr. Pye-Smith and Professors de Chaumont, M. Foster, and Burdon Sanderson be reappointed a Committee for the purpose of investigating the Influence of Bodily Exercise on the Elimination of Nitrogen (the experiments to be conducted by Mr. North); and that Professor Burdon Sanderson be the Secretary.

That Mr. James Glaisher, the Rev. Canon Tristram, and the Rev. F. Lawrence be reappointed a Committee for promoting the Survey of Eastern Palestine; and that Mr. James Glaisher be the Secretary.

That Dr. Gladstone (Secretary), Mr. W. Shaen, Mr. Stephen Bourne, Miss Lydia Becker, Sir J. Lubbock, Dr. H. W. Crosskey, Professor Roscoe, and Mr. James Heywood be a Committee for the purpose of continuing the inquiries of a similar Committee appointed last year relating to the teaching of Science in Elementary Schools.

That the Special Committee appointed to watch and report on the workings of the Code and other legislation affecting the teaching of science in Elementary Schools be requested to consider the desirableness of making representations to the Lords of the Committee of Her Majesty's Privy Council on Education in favour of aid being extended towards the fitting up of workshops in connection with elementary day schools or evening classes, and of making grants on the results of practical instruction in such workshops under suitable direction, and if necessary to communicate with the Council.

Reports on Progress in Science.

That Mr. R. T. Glazebrook be requested to report on recent progress in Physical Optics.

That Mr. J. J. Thomson be requested to draw up a report on Electrical Theories.

That Mr. W. Topley be requested to report upon National Geological Surveys.

That Mr. F. Drew and Professor A. H. Green be requested to report upon the present state of knowledge respecting the Interior of the Earth.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

Dr. Huggins' paper 'On a Method of photographing the Solar Corona without an Eclipse.'

Professor Lindemann's paper 'On Lamé's Differential Equation.'

Professor Leone Levi's paper 'On the Distribution of Wealth.'

Professor Fleeming Jenkin's paper on 'Nest Gearing.'

Mr. C. D. Fox's paper 'On the Mersey Tunnel' (with diagrams).

Mr. Parsons' paper 'On Manganese Bronze.'

Resolutions referred to the Council for Consideration, and Action, if desirable.

That the Council be empowered, if they think fit, to form a separate section of Anthropology, and to give to the section of Biology the title, 'Section D—Biology (Zoology, Botany, and Physiology).'

That application be made to the Admiralty to institute a Physical and Biological Survey of Milford Haven and the adjacent coast of Pembrokeshire, on the plan followed by the American Fisheries Commission.

That the Council of the British Association be requested to consider the report of the Committee of Section A respecting the suppression of four

of the seven principal observatories of the Meteorological Council, and to forward a copy of the same to the Meteorological Council.

That the Council of the British Association be requested to communicate at the earliest opportunity with the Executive Committee of the International Fisheries Exhibition in order to urge upon that body the appropriation of a sufficient sum out of the surplus funds remaining in their hands at the close of the Exhibition to found a laboratory on the British Coast for the study of Marine Zoology; and to point out, as a reason for such appropriation, the great value to science, and to the prosperity of the fisheries industries, of such an institution.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Southport Meeting in September 1883. *The Names of the Members who are entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

	£	s.	d.
*Brown, Professor Crum.—Meteorological Observations on Ben Nevis	50	0	0
*Foster, Professor G. Carey.—Electrical Standards	50	0	0
*Schuster, Professor.—Meteoric Dust	20	0	0
*Abney, Captain.—Standard of White Light	20	0	0
*Scott, Mr. R. H.—Synoptic Charts of the Indian Ocean	50	0	0
Stewart, Professor Balfour.—Meteorological Observations near Chepstow	25	0	0
Shoolbred, Mr. J. N.—Reduction of Tidal Observations	10	0	0
*Darwin, Professor G. H.—Harmonic Analysis of Tidal Observations	45	0	0

Chemistry.

*Odling, Professor.—Photographing the Ultra-Violet Spark-Spectra	10	0	0

Geology.

*Etheridge, Mr. R.—Earthquake Phenomena of Japan	75	0	0
*Williamson, Professor W. C.—Fossil Plants of Halifax	15	0	0
*Sorby, Dr. H. C.—British Fossil Polyzoa	10	0	0
*Prestwich, Professor.—Erratic Blocks	10	0	0
*Etheridge, Mr. R.—Fossil Phyllopoda of the Palæozoic Rocks	15	0	0
*Hull, Professor E.—Circulation of Underground Waters	15	0	0
*Evans, Dr. J.—Geological Record	15	0	0
*Green, Professor A. H.—Raygill Fissure	15	0	0
*Prestwich, Professor.—International Geological Map of Europe	20	0	0
Carried forward	£470	0	0

* Reappointed.

	£	s.	d.
Brought forward	470	0	0

Biology.

	£	s.	d.
Newton, Professor.—Zoological Bibliography	50	0	0
*Sclater, Mr. P. L.—Natural History of Timor-laut	50	0	0
*Lankester, Professor Ray.—Table at the Zoological Station at Naples	80	0	0
*Harrison, J. Park.—Facial Characteristics of Races in the British Isles	10	0	0
*Hooker, Sir J.—Exploring Kilimanjaro and the adjoining Mountains of Equatorial Africa	500	0	0
*Cordeaux, Mr. J.—Migration of Birds	20	0	0
Foster, Dr. M.—Coagulation of the Blood	50	0	0
*Stainton, Mr. H. T.—Record of Zoological Literature	100	0	0

Geography.

	£	s.	d.
Godwin-Austen, Lieut.-Colonel.—Exploration of New Guinea	100	0	0

Economic Science and Statistics.

	£	s.	d.
*Brabrook, Mr. E. W.—Preparation of the final Report of the Anthropometric Committee	10	0	0

Mechanics.

	£	s.	d.
*Bramwell, Sir F.—Patent Legislation	5	0	0
	£1445	0	0

* Reappointed.

The Annual Meeting in 1884.

The Meeting at Montreal will commence on Wednesday, August 27.

Place of Meeting in 1885.

The Annual Meeting of the Association in 1885 will be held at Aberdeen.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

	£	s.	d.
1844.			
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology......1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8
1845.			
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9
1846.			
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0
1847.			
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

	£	s.	d.
1848.			
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8
1849.			
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6
1850.			
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

	£	s.	d.
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854 ... £ 75 0 0; 1855 ... £500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool ...	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance...	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den ...	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance ...	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium ...	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcon Quatries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Eliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid..............	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland......	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record...............	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall..................	100	0	0
Ohm's Law........................	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate..........................	5	0	0
Estimation of Potash and Phosphoric Acid..............	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record..............	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland......	1	10	0
Zoological Record..............	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station...............	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles......	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record..............	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on......	20	0	0
Mechanical Equivalent of Heat............................	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid...............	1	18	0
Geological Record...............	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c................	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record...............	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters...........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure..........................	30	0	0
Calculation of Factor Table of Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less known Alkaloids........................	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors...............	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration ...	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee...	50	0	0
Natural History of Socotra ...	100	0	0
Calculation of Factor Tables for 5th and 6th Millions ...	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers...	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature ...	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration...	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
Electrical Standards	25	0	0
Anthropological Notes and Queries	9	0	0
Specific Refractions	7	3	1
	£476	3	1

1882.

	£	s.	d.
Tertiary Flora of North of Ireland	20	0	0
Exploration of Caves of South of Ireland	10	0	0
Fossil Plants of Halifax	15	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Record of Zoological Literature	100	0	0
British Fossil Polyzoa	10	0	0
Naples Zoological Station ...	80	0	0
Natural History of Timor-laut	100	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Natural History of Socotra...	100	0	0
Circulation of Underground Waters	15	0	0
Migration of Birds	15	0	0
Earthquake Phenomena of Japan	25	0	0

	£	s.	d.
Geological Map of Europe ...	25	0	0
Elimination of Nitrogen by Bodily Exercise...............	50	0	0
Anthropometric Committee...	50	0	0
Photographing Ultra-Violet Spark Spectra	25	0	0
Exploration of Raygill Fissure	20	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-lengths Tables of Spectra of Elements...............	50	0	0
Geological Record...............	100	0	0
Standards for Electrical Measurements	100	0	0
Exploration of Central Africa	100	0	0
Albuminoid Substances of Serum	10	0	0
	£1126	1	11

1883.

	£	s.	d.
Natural History of Timor-laut	50	0	0
British Fossil Polyzoa	10	0	0
Circulation of Underground Waters............................	15	0	0
Zoological Literature Record	100	0	0
Exploration of Mount Kilimanjaro	500	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Fossil Plants of Halifax	20	0	0
Elimination of Nitrogen by Bodily Exercise...............	38	3	3
Isomeric Naphthalene Derivatives............................	15	0	0
Zoological Station at Naples	80	0	0
Investigation of Loughton Camp	10	0	0
Earthquake Phenomena of Japan	50	0	0
Meteorological Observations on Ben Nevis	50	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Migration of Birds	20	0	0
Geological Record...............	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Scottish Zoological Station ...	25	0	0
Screw Gauges......................	5	0	0
	£1083	3	3

General Meetings—in the Winter Gardens.

On Wednesday, September 19, at 8 P.M., Sir W. Siemens, D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E., resigned the office of President to Professor Cayley, M.A., LL.D., F.R.S., V.P.R.A.S., who took the Chair, and delivered an Address, for which see page 1.

On Thursday, September 20, at 8 P.M., a Soirée took place.

On Friday, September 21, at 8.30 P.M., Professor R. S. Ball, LL.D., F.R.S., Astronomer Royal for Ireland, delivered a Discourse on 'Recent Researches on the Distance of the Sun.'

On Monday, September 24, at 8.30 P.M., Professor J. G. McKendrick, M.D., F.R.S.E., delivered a Discourse on 'Galvani and Animal Electricity.'

On Tuesday, September 25, at 8 P.M., a Soirée took place.

On Wednesday, September 26, at 2.30 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The meeting was then adjourned to Montreal. [The Meeting is appointed to commence on Wednesday, August 27, 1884.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

ARTHUR CAYLEY,

M.A., D.C.L., LL.D., F.R.S., *Sadlerian Professor of Pure Mathematics in the University of Cambridge,*

PRESIDENT.

Since our last meeting we have been deprived of three of our most distinguished members. The loss by the death of Professor Henry John Stephen Smith is a very grievous one to those who knew and admired and loved him, to his University, and to mathematical science, which he cultivated with such ardour and success. I need hardly recall that the branch of mathematics to which he had specially devoted himself was that most interesting and difficult one, the Theory of Numbers. The immense range of this subject, connected with and ramifying into so many others, is nowhere so well seen as in the series of reports on the progress thereof, brought up unfortunately only to the year 1865, contributed by him to the Reports of the Association; but it will still better appear when to these are united (as will be done in the collected works in course of publication by the Clarendon Press) his other mathematical writings, many of them containing his own further developments of theories referred to in the reports. There have been recently or are being published many such collected editions—Abel, Cauchy, Clifford, Gauss, Green, Jacobi, Lagrange, Maxwell, Riemann, Steiner. Among these the works of Henry Smith will occupy a worthy position.

More recently, General Sir Edward Sabine, K.C.B., for twenty-one years general secretary of the Association, and a trustee, President of the meeting at Belfast in the year 1852, and for many years treasurer and afterwards President of the Royal Society, has been taken from us, at an age exceeding the ordinary age of man. Born October 1788, he entered the Royal Artillery in 1803, and commanded batteries at the siege of Fort Erie in 1814; made magnetic and other observations in Ross and Parry's North Polar exploration in 1818–19, and in a series of other voyages. He contributed to the Association reports on Magnetic Forces in 1836–7–8, and about forty papers to the Philosophical Transactions; originated the system of Magnetic Observatories, and otherwise signally promoted the science of Terrestrial Magnetism.

There is yet a very great loss—another late President and trustee of

the Association, one who has done for it so much, and has so often attended the meetings, whose presence among us at this meeting we might have hoped for—the President of the Royal Society, William Spottiswoode. It is unnecessary to say anything of his various merits: the place of his burial, the crowd of sorrowing friends who were present in the Abbey, bear witness to the esteem in which he was held.

I take the opportunity of mentioning the completion of a work promoted by the Association: the determination by Mr. James Glaisher of the least factors of the missing three out of the first nine million numbers: the volume containing the sixth million is now published.

I wish to speak to you to-night upon Mathematics. I am quite aware of the difficulty arising from the abstract nature of my subject; and if, as I fear, many or some of you, recalling the Presidential Addresses at former meetings—for instance, the *résumé* and survey which we had at York of the progress, during the half-century of the lifetime of the Association, of a whole circle of sciences—Biology, Palæontology, Geology, Astronomy, Chemistry—so much more familiar to you, and in which there was so much to tell of the fairy-tales of science; or at Southampton, the discourse of my friend who has in such kind terms introduced me to you, on the wondrous practical applications of science to electric lighting, telegraphy, the St. Gothard Tunnel and the Suez Canal, gun-cotton, and a host of other purposes, and with the grand concluding speculation on the conservation of solar energy: if, I say, recalling these or any earlier Addresses, you should wish that you were now about to have, from a different President, a discourse on a different subject, I can very well sympathise with you in the feeling.

But, be this as it may, I think it is more respectful to you that I should speak to you upon and do my best to interest you in the subject which has occupied me, and in which I am myself most interested. And in another point of view, I think it is right that the Address of a President should be on his own subject, and that different subjects should be thus brought in turn before the meetings. So much the worse, it may be, for a particular meeting; but the meeting is the individual, which on evolution principles must be sacrificed for the development of the race.

Mathematics connect themselves on the one side with common life and the physical sciences; on the other side with philosophy, in regard to our notions of space and time, and in the questions which have arisen as to the universality and necessity of the truths of mathematics, and the foundation of our knowledge of them. I would remark here that the connection (if it exists) of arithmetic and algebra with the notion of time is far less obvious than that of geometry with the notion of space.

As to the former side, I am not making before you a defence of mathematics, but if I were I should desire to do it—in such manner as in the 'Republic' Socrates was required to defend justice—quite irrespectively of the worldly advantages which may accompany a life of virtue and

justice, and to show that, independently of all these, justice was a thing desirable in itself and for its own sake—*not* by speaking to you of the utility of mathematics in any of the questions of common life or of physical science. Still less would I speak of this utility before, I trust, a friendly audience, interested or willing to appreciate an interest in mathematics in itself and for its own sake. I would, on the contrary, rather consider the obligations of mathematics to these different subjects as the sources of mathematical theories now as remote from them, and in as different a region of thought—for instance, geometry from the measurement of land, or the Theory of Numbers from arithmetic—as a river at its mouth is from its mountain source.

On the other side, the general opinion has been and is that it is indeed by experience that we arrive at the truths of mathematics, but that experience is not their proper foundation : the mind itself contributes something. This is involved in the Platonic theory of reminiscence ; looking at two things, trees or stones or anything else, which seem to us more or less equal, we arrive at the idea of equality : but we must have had this idea of equality before the time when first seeing the two things we were led to regard them as coming up more or less perfectly to this idea of equality ; and the like as regards our idea of the beautiful, and in other cases.

The same view is expressed in the answer of Leibnitz, the *nisi intellectus ipse*, to the scholastic dictum, *nihil in intellectu quod non prius in sensu* : there is nothing in the intellect which was not first in sensation, except (said Leibnitz) the intellect itself. And so again in the 'Critick of Pure Reason,' Kant's view is that while there is no doubt but that all our cognition begins with experience, we are nevertheless in possession of cognitions *a priori*, independent, not of this or that experience, but absolutely so of all experience, and in particular that the axioms of mathematics furnish an example of such cognitions *a priori*. Kant holds further that space is no empirical conception which has been derived from external experiences, but that in order that sensations may be referred to something external, the representation of space must already lie at the foundation ; and that the external experience is itself first only possible by this representation of space. And in like manner time is no empirical conception which can be deduced from an experience, but it is a necessary representation lying at the foundation of all intuitions.

And so in regard to mathematics, Sir W. R. Hamilton, in an Introductory Lecture on Astronomy (1836), observes : 'These purely mathematical sciences of algebra and geometry are sciences of the pure reason, deriving no weight and no assistance from experiment, and isolated or at least isolable from all outward and accidental phenomena. The idea of order with its subordinate ideas of number and figure, we must not indeed call innate ideas, if that phrase be defined to imply that all men must possess them with equal clearness and fulness : they are, however, ideas which seem to be so far born with us that the possession of them in any con-

ceivable degree is only the development of our original powers, the unfolding of our proper humanity.'

The general question of the ideas of space and time, the axioms and definitions of geometry, the axioms relating to number, and the nature of mathematical reasoning, are fully and ably discussed in Whewell's 'Philosophy of the Inductive Sciences' (1840), which may be regarded as containing an exposition of the whole theory.

But it is maintained by John Stuart Mill that the truths of mathematics, in particular those of geometry, rest on experience; and as regards geometry, the same view is on very different grounds maintained by the mathematician Riemann.

It is not so easy as at first sight it appears to make out how far the views taken by Mill in his 'System of Logic Ratiocinative and Inductive' (9th ed. 1879) are absolutely contradictory to those which have been spoken of; they profess to be so; there are most definite assertions (supported by argument), for instance, p. 263 :—'It remains to enquire what is the ground of our belief in axioms, what is the evidence on which they rest. I answer, they are experimental truths, generalisations from experience. The proposition "Two straight lines cannot enclose a space," or, in other words, two straight lines which have once met cannot meet again, is an induction from the evidence of our senses.' But I cannot help considering a previous argument (p. 259) as very materially modifying this absolute contradiction. After enquiring 'Why are mathematics by almost all philosophers . . . considered to be independent of the evidence of experience and observation, and characterised as systems of necessary truth?' Mill proceeds (I quote the whole passage) as follows :—'The answer I conceive to be that this character of necessity ascribed to the truths of mathematics, and even (with some reservations to be hereafter made) the peculiar certainty ascribed to them, is a delusion, in order to sustain which it is necessary to suppose that those truths relate to and express the properties of purely imaginary objects. It is acknowledged that the conclusions of geometry are derived partly at least from the so-called definitions, and that these definitions are assumed to be correct representations, as far as they go, of the objects with which geometry is conversant. Now, we have pointed out that from a definition as such no proposition unless it be one concerning the meaning of a word can ever follow, and that what apparently follows from a definition, follows in reality from an implied assumption that there exists a real thing conformable thereto. This assumption in the case of the definitions of geometry is not strictly true: there exist no real things exactly conformable to the definitions. There exist no real points without magnitude, no lines without breadth, nor perfectly straight, no circles with all their radii exactly equal, nor squares with all their angles perfectly right. It will be said that the assumption does not extend to the actual but only to the possible existence of such things. I answer that according to every test we have of possibility they are not even possible. Their existence, so far as

we can form any judgment, would seem to be inconsistent with the physical constitution of our planet at least, if not of the universal [*sic*]. To get rid of this difficulty and at the same time to save the credit of the supposed system of necessary truth, it is customary to say that the points, lines, circles and squares which are the subjects of geometry exist in our conceptions merely and are parts of our minds; which minds by working on their own materials construct an *a priori* science, the evidence of which is purely mental and has nothing to do with outward experience. By howsoever high authority this doctrine has been sanctioned, it appears to me psychologically incorrect. The points, lines and squares which anyone has in his mind are (as I apprehend) simply copies of the points, lines and squares which he has known in his experience. Our idea of a point I apprehend to be simply our idea of the *minimum visibile*, the small portion of surface which we can see. We can reason about a line as if it had no breadth, because we have a power which we can exercise over the operations of our minds: the power, when a perception is present to our senses or a conception to our intellects, of *attending* to a part only of that perception or conception instead of the whole. But we cannot *conceive* a line without breadth: we can form no mental picture of such a line; all the lines which we have in our mind are lines possessing breadth. If anyone doubt this, we may refer him to his own experience. I much question if anyone who fancies that he can conceive of a mathematical line thinks so from the evidence of his own consciousness. I suspect it is rather because he supposes that unless such a perception be possible, mathematics could not exist as a science: a supposition which there will be no difficulty in showing to be groundless.'

I think it may be at once conceded that the truths of geometry are truths precisely because they relate to and express the properties of what Mill calls 'purely imaginary objects;' that these objects do not exist in Mill's sense, that they do not exist in nature, may also be granted; that they are 'not even possible,' if this means not possible in an existing nature, may also be granted. That we cannot 'conceive' them depends on the meaning which we attach to the word conceive. I would myself say that the purely imaginary objects are the only realities, the ὄντως ὄντα, in regard to which the corresponding physical objects are as the shadows in the cave; and it is only by means of them that we are able to deny the existence of a corresponding physical object; if there is no conception of straightness, then it is meaningless to deny the existence of a perfectly straight line.

But at any rate the objects of geometrical truth are the so-called imaginary objects of Mill, and the truths of geometry are only true, and *a fortiori* are only necessarily true, in regard to these so-called imaginary objects; and these objects, points, lines, circles, &c., in the mathematical sense of the terms, have a likeness to and are represented more or less imperfectly, and from a geometer's point of view no matter how imperfectly, by corresponding physical points, lines, circles, &c. I shall have to return

to geometry, and will then speak of Riemann, but I will first refer to another passage of the Logic.

Speaking of the truths of arithmetic Mill says (p. 297) that even here there is one hypothetical element: 'In all propositions concerning numbers a condition is implied without which none of them would be true, and that condition is an assumption which may be false. The condition is that 1=1 : that all the numbers are numbers of the same or of equal units.' Here at least the assumption may be absolutely true; one shilling = one shilling in purchasing power, although they may not be absolutely of the same weight and fineness: but it is hardly necessary; one coin + one coin = two coins, even if the one be a shilling and the other a half-crown. In fact, whatever difficulty be raisable as to geometry, it seems to me that no similar difficulty applies to arithmetic; mathematician or not, we have each of us, in its most abstract form, the idea of a number; we can each of us appreciate the truth of a proposition in regard to numbers; and we cannot but see that a truth in regard to numbers is something different in kind from an experimental truth generalised from experience. Compare, for instance, the proposition that the sun, having already risen so many times, will rise to-morrow, and the next day, and the day after that, and so on; and the proposition that even and odd numbers succeed each other alternately *ad infinitum*: the latter at least seems to have the characters of universality and necessity. Or again, suppose a proposition observed to hold good for a long series of numbers, one thousand numbers, two thousand numbers, as the case may be: this is not only no proof, but it is absolutely no evidence, that the proposition is a true proposition, holding good for all numbers whatever; there are in the Theory of Numbers very remarkable instances of propositions observed to hold good for very long series of numbers, which are nevertheless untrue.

I pass in review certain mathematical theories.

In arithmetic and algebra, or say in analysis, the numbers or magnitudes which we represent by symbols are in the first instance ordinary (that is, positive) numbers or magnitudes. We have also in analysis and in analytical geometry *negative* magnitudes; there has been in regard to these plenty of philosophical discussion, and I might refer to Kant's paper, 'Ueber die negativen Grössen in die Weltweisheit' (1763), but the notion of a negative magnitude has become quite a familiar one, and has extended itself into common phraseology. I may remark that it is used in a very refined manner in bookkeeping by double entry.

But it is far otherwise with the notion which is really the fundamental one (and I cannot too strongly emphasise the assertion) underlying and pervading the whole of modern analysis and geometry, that of imaginary magnitude in analysis and of imaginary space (or space as a *locus in quo* of imaginary points and figures) in geometry: I use in each case the word imaginary as including real. This has not been, so far as

I am aware, a subject of philosophical discussion or enquiry. As regards the older metaphysical writers this would be quite accounted for by saying that they knew nothing, and were not bound to know anything, about it; but at present, and, considering the prominent position which the notion occupies—say even that the conclusion were that the notion belongs to mere technical mathematics, or has reference to nonentities in regard to which no science is possible, still it seems to me that (as a subject of philosophical discussion) the notion ought not to be thus ignored; it should at least be shown that there is a right to ignore it.

Although in logical order I should perhaps now speak of the notion just referred to, it will be convenient to speak first of some other quasi-geometrical notions; those of more-than-three-dimensional space, and of non-Euclidian two- and three-dimensional space, and also of the generalised notion of distance. It is in connection with these that Riemann considered that our notion of space is founded on experience, or rather that it is only by experience that we know that our space is Euclidian space.

It is well known that Euclid's twelfth axiom, even in Playfair's form of it, has been considered as needing demonstration; and that Lobatschewsky constructed a perfectly consistent theory, wherein this axiom was assumed not to hold good, or say a system of non-Euclidian plane geometry. There is a like system of non-Euclidian solid geometry. My own view is that Euclid's twelfth axiom in Playfair's form of it does not need demonstration, but is part of our notion of space, of the physical space of our experience—the space, that is, which we become acquainted with by experience, but which is the representation lying at the foundation of all external experience. Riemann's view before referred to may I think be said to be that, having *in intellectu* a more general notion of space (in fact a notion of non-Euclidian space), we learn by experience that space (the physical space of our experience) is, if not exactly, at least to the highest degree of approximation, Euclidian space.

But suppose the physical space of our experience to be thus only approximately Euclidian space, what is the consequence which follows? *Not* that the propositions of geometry are only approximately true, but that they remain absolutely true in regard to that Euclidian space which has been so long regarded as being the physical space of our experience.

It is interesting to consider two different ways in which, without any modification at all of our notion of space, we can arrive at a system of non-Euclidian (plane or two-dimensional) geometry; and the doing so will, I think, throw some light on the whole question.

First, imagine the earth a perfectly smooth sphere; understand by a plane the surface of the earth, and by a line the apparently straight line (in fact an arc of a great circle) drawn on the surface; what experience would in the first instance teach would be Euclidian geometry; there would be intersecting lines which produced a few miles or so would

seem to go on diverging: and apparently parallel lines which would exhibit no tendency to approach each other; and the inhabitants might very well conceive that they had by experience established the axiom that two straight lines cannot enclose a space, and the axiom as to parallel lines. A more extended experience and more accurate measurements would teach them that the axioms were each of them false; and that any two lines, if produced far enough each way, would meet in two points: they would in fact arrive at a spherical geometry, accurately representing the properties of the two-dimensional space of their experience. But their original Euclidian geometry would not the less be a true system: only it would apply to an ideal space, not the space of their experience.

Secondly, consider an ordinary, indefinitely extended plane; and let us modify only the notion of distance. We measure distance, say, by a yard measure or a foot rule, anything which is short enough to make the fractions of it of no consequence (in mathematical language by an infinitesimal element of length); imagine, then, the length of this rule constantly changing (as it might do by an alteration of temperature), but under the condition that its actual length shall depend only on its situation on the plane and on its direction: viz. if for a given situation and direction it has a certain length, then whenever it comes back to the same situation and direction it must have the same length. The distance along a given straight or curved line between any two points could then be measured in the ordinary manner with this rule, and would have a perfectly determinate value: it could be measured over and over again, and would always be the same; but of course it would be the distance, not in the ordinary acceptation of the term, but in quite a different acceptation. Or in a somewhat different way: if the rate of progress from a given point in a given direction be conceived as depending only on the configuration of the ground, and the distance along a given path between any two points thereof be measured by the time required for traversing it, then in this way also the distance would have a perfectly determinate value; but it would be a distance, not in the ordinary acceptation of the term, but in quite a different acceptation. And corresponding to the new notion of distance we should have a new, non-Euclidian system of plane geometry; all theorems involving the notion of distance would be altered.

We may proceed further. Suppose that as the rule moves away from a fixed central point of the plane it becomes shorter and shorter; if this shortening takes place with sufficient rapidity, it may very well be that a distance which in the ordinary sense of the word is finite will in the new sense be infinite; no number of repetitions of the length of the ever-shortening rule will be sufficient to cover it. There will be surrounding the central point a certain finite area such that (in the new acceptation of the term distance) each point of the boundary thereof will be at an infinite distance from the central point; the points outside this area you

cannot by any means arrive at with your rule; they will form a *terra incognita*, or rather an unknowable land: in mathematical language, an imaginary or impossible space: and the plane space of the theory will be that within the finite area—that is, it will be finite instead of infinite.

We thus with a proper law of shortening arrive at a system of non-Euclidian geometry which is essentially that of Lobatschewsky. But in so obtaining it we put out of sight its relation to spherical geometry: the three geometries (spherical, Euclidian, and Lobatschewsky's) should be regarded as members of a system: viz., they are the geometries of a plane (two-dimensional) space of constant positive curvature, zero curvature, and constant negative curvature respectively; or again, they are the plane geometries corresponding to three different notions of distance; in this point of view they are Klein's elliptic, parabolic, and hyperbolic geometries respectively.

Next as regards solid geometry: we can by a modification of the notion of distance (such as has just been explained in regard to Lobatschewsky's system) pass from our present system to a non-Euclidian system; for the other mode of passing to a non-Euclidian system it would be necessary to regard our space as a flat three-dimensional space existing in a space of four dimensions (*i.e.*, as the analogue of a plane existing in ordinary space); and to substitute for such flat three-dimensional space a curved three-dimensional space, say of constant positive or negative curvature. In regarding the physical space of our experience as possibly non-Euclidian, Riemann's idea seems to be that of modifying the notion of distance, not that of treating it as a locus in four-dimensional space.

I have just come to speak of four-dimensional space. What meaning do we attach to it? Or can we attach to it any meaning? It may be at once admitted that we cannot conceive of a fourth dimension of space; that space as we conceive of it, and the physical space of our experience, are alike three-dimensional; but we can, I think, conceive of space as being two- or even one-dimensional; we can imagine rational beings living in a one-dimensional space (a line) or in a two-dimensional space (a surface), and conceiving of space accordingly, and to whom, therefore, a two-dimensional space, or (as the case may be) a three-dimensional space would be as inconceivable as a four-dimensional space is to us. And very curious speculative questions arise. Suppose the one-dimensional space a right line, and that it afterwards becomes a curved line: would there be any indication of the change? Or, if originally a curved line, would there be anything to suggest to them that it was not a right line? Probably not, for a one-dimensional geometry hardly exists. But let the space be two-dimensional, and imagine it originally a plane, and afterwards bent (converted, that is, into some form of developable surface) or converted into a curved surface: or imagine it originally a developable or curved surface. In the former case there should be an indication of the change, for the geometry originally applicable to the space of their

experience (our own Euclidian geometry) would cease to be applicable; but the change could not be apprehended by them as a bending or deformation of the plane, for this would imply the notion of a three-dimensional space in which this bending or deformation could take place. In the latter case their geometry would be that appropriate to the developable or curved surface which is their space: viz. this would be their Euclidian geometry: would they ever have arrived at our own more simple system? But take the case where the two-dimensional space is a plane, and imagine the beings of such a space familiar with our own Euclidian plane geometry; if, a third dimension being still inconceivable by them, they were by their geometry or otherwise led to the notion of it, there would be nothing to prevent them from forming a science such as our own science of three-dimensional geometry.

Evidently all the foregoing questions present themselves in regard to ourselves, and to three-dimensional space as we conceive of it, and as the physical space of our experience. And I need hardly say that the first step is the difficulty, and that granting a fourth dimension we may assume as many more dimensions as we please. But whatever answer be given to them, we have, as a branch of mathematics, potentially, if not actually, an analytical geometry of n-dimensional space. I shall have to speak again upon this.

Coming now to the fundamental notion already referred to, that of imaginary magnitude in analysis and imaginary space in geometry: I connect this with two great discoveries in mathematics made in the first half of the seventeenth century, Harriot's representation of an equation in the form $f(x)=0$, and the consequent notion of the roots of an equation as derived from the linear factors of $f(x)$, (Harriot, 1560–1621: his 'Algebra,' published after his death, has the date 1631), and Descartes' method of coordinates, as given in the 'Géometrie,' forming a short supplement to his 'Traité de la Méthode etc.' (Leyden, 1637).

Taking the coefficients of an equation to be real magnitudes, it at once follows from Harriot's form of an equation that an equation of the order n ought to have n roots. But it is by no means true that there are always n real roots. In particular, an equation of the second order, or quadric equation, may have no real root; but if we assume the existence of a root i of the quadric equation $x^2+1=0$, then the other root is $=-i$; and it is easily seen that every quadric equation (with real coefficients as before) has two roots, $a \pm bi$, where a and b are real magnitudes. We are thus led to the conception of an imaginary magnitude, $a+bi$, where a and b are real magnitudes, each susceptible of any positive or negative value, zero included. The general theorem is that, taking the coefficients of the equation to be imaginary magnitudes, then an equation of the order n has always n roots, each of them an imaginary magnitude, and it thus appears that the foregoing form $a+bi$ of imaginary magnitude is the only one that presents itself. Such imaginary

magnitudes may be added or multiplied together or dealt with in any manner; the result is always a like imaginary magnitude. They are thus the magnitudes which are considered in analysis, and analysis is the science of such magnitudes. Observe the leading character that the imaginary magnitude $a + bi$ is a magnitude composed of the two real magnitudes a and b (in the case $b = 0$ it is the real magnitude a, and in the case $a = 0$ it is the pure imaginary magnitude bi). The idea is that of considering, in place of real magnitudes, these imaginary or complex magnitudes $a + bi$.

In the Cartesian geometry a curve is determined by means of the equation existing between the coordinates (x, y) of any point thereof. In the case of a right line this equation is linear; in the case of a circle, or more generally of a conic, the equation is of the second order; and generally, when the equation is of the order n, the curve which it represents is said to be of a curve of the order n. In the case of two given curves there are thus two equations satisfied by the coordinates (x, y) of the several points of intersection, and these give rise to an equation of a certain order for the coordinate x or y of a point of intersection. In the case of a straight line and a circle this is a quadric equation; it has two roots, real or imaginary. There are thus two values, say of x, and to each of these corresponds a single value of y. There are therefore two points of intersection—viz. a straight line and a circle intersect *always* in two points, real or imaginary. It is in this way that we are led analytically to the notion of imaginary points in geometry. The conclusion as to the two points of intersection cannot be contradicted by experience: take a sheet of paper and draw on it the straight line and circle, and try. But you might say, or at least be strongly tempted to say, that it is meaningless. The question of course arises, What is the meaning of an imaginary point? and further, In what manner can the notion be arrived at geometrically?

There is a well-known construction in perspective for drawing lines through the intersection of two lines, which are so nearly parallel as not to meet within the limits of the sheet of paper. You have two given lines which do not meet, and you draw a third line, which, when the lines are all of them produced, is found to pass through the intersection of the given lines. If instead of lines we have two circular arcs not meeting each other, then we can, by means of these arcs, construct a line; and if on completing the circles it is found that the circles intersect each other in two real points, then it will be found that the line passes through these two points: if the circles appear not to intersect, then the line will appear not to intersect either of the circles. But the geometrical construction being in each case the same, we say that in the second case also the line passes through the two intersections of the circles.

Of course it may be said in reply that the conclusion is a very natural one, provided we assume the existence of imaginary points; and that, this assumption not being made, then, if the circles do not intersect, it is

meaningless to assert that the line passes through their points of intersection. The difficulty is not got over by the analytical method before referred to, for this introduces difficulties of its own: is there in a plane a point the coordinates of which have given imaginary values? As a matter of fact, we do consider in plane geometry imaginary points introduced into the theory analytically or geometrically as above.

The like considerations apply to solid geometry, and we thus arrive at the notion of imaginary space as a *locus in quo* of imaginary points and figures.

I have used the word imaginary rather than complex, and I repeat that the word has been used as including real. But, this once understood, the word becomes in many cases superfluous, and the use of it would even be misleading. Thus, 'a problem has so many solutions:' this means, so many imaginary (including real) solutions. But if it were said that the problem had 'so many imaginary solutions,' the word 'imaginary' would here be understood to be used in opposition to real. I give this explanation the better to point out how wide the application of the notion of the imaginary is—viz. (unless expressly or by implication excluded), it is a notion implied and presupposed in all the conclusions of modern analysis and geometry. It is, as I have said, the fundamental notion underlying and pervading the whole of these branches of mathematical science.

I shall speak later on of the great extension which is thereby given to geometry, but I wish now to consider the effect as regards the theory of a function. In the original point of view, and for the original purposes, a function, algebraic or transcendental, such as $\sqrt{x}$, $\sin x$, or $\log x$, was considered as known, when the value was known for every real value (positive or negative) of the argument; or if for any such values the value of the function became imaginary, then it was enough to know that for such values of the argument there was no real value of the function. But now this is not enough, and to know the function means to know its value—of course, in general, an imaginary value $X + iY$,—for every imaginary value $x + iy$ whatever of the argument.

And this leads naturally to the question of the geometrical representation of an imaginary variable. We represent the imaginary variable $x + iy$ by means of a point in a plane, the coordinates of which are (x, y). This idea, due to Gauss, dates from about the year 1831. We thus picture to ourselves the succession of values of the imaginary variable $x + iy$ by means of the motion of the representative point: for instance, the succession of values corresponding to the motion of the point along a closed curve to its original position. The value $X + iY$ of the function can of course be represented by means of a point (taken for greater convenience in a different plane), the coordinates of which are X, Y.

We may consider in general two points, moving each in its own plane, so that the position of one of them determines the position of the

other, and consequently the motion of the one determines the motion of the other: for instance, the two points may be the tracing-point and the pencil of a pentagraph. You may with the first point draw any figure you please, there will be a corresponding figure drawn by the second point: for a good pentagraph, a copy on a different scale (it may be); for a badly-adjusted pentagraph, a distorted copy: but the one figure will always be a sort of copy of the first, so that to each point of the one figure there will correspond a point of the other figure.

In the case above referred to, where one point represents the value $x + iy$ of the imaginary variable and the other the value $X + iY$ of some function $\phi(x + iy)$ of that variable, there is a remarkable relation between the two figures: this is the relation of orthomorphic projection, the same which presents itself between a portion of the earth's surface, and the representation thereof by a map on the stereographic projection or on Mercator's projection—viz. any indefinitely small area of the one figure is represented in the other figure by an indefinitely small area of the same shape. There will possibly be for different parts of the figure great variations of scale, but the shape will be unaltered; if for the one area the boundary is a circle, then for the other area the boundary will be a circle; if for one it is an equilateral triangle, then for the other it will be an equilateral triangle.

I have for simplicity assumed that to each point of either figure there corresponds one, and only one, point of the other figure; but the general case is that to each point of either figure there corresponds a determinate number of points in the other figure; and we have thence arising new and very complicated relations which I must just refer to. Suppose that to each point of the first figure there correspond in the second figure two points: say one of them is a red point, the other a blue point; so that, speaking roughly, the second figure consists of two copies of the first figure, a red copy and a blue copy, the one superimposed on the other. But the difficulty is that the two copies cannot be kept distinct from each other. If we consider in the first figure a closed curve of any kind—say, for shortness, an oval—this will be in the second figure represented in some cases by a red oval and a blue oval, but in other cases by an oval half red and half blue; or, what comes to the same thing, if in the first figure we consider a point which moves continuously in any manner, at last returning to its original position, and attempt to follow the corresponding points in the second figure, then it may very well happen that, for the corresponding point of either colour, there will be abrupt changes of position, or say jumps, from one position to another; so that, to obtain in the second figure a continuous path, we must at intervals allow the point to change from red to blue, or from blue to red. There are in the first figure certain critical points called branch-points (*Verzweigungs-punkte*), and a system of lines connecting these, by means of which the colours in the second figure are determined; but it is not possible for me to go further into the theory at present. The notion of colour has of

course been introduced only for facility of expression; it may be proper to add that in speaking of the two figures I have been following Briot and Bouquet rather than Riemann, whose representation of the function of an imaginary variable is a different one.

I have been speaking of an imaginary variable $(x + iy)$, and of a function $\phi(x + iy) = X + iY$ of that variable, but the theory may equally well be stated in regard to a plane curve: in fact, the $x + iy$ and the $X + iY$ are two imaginary variables connected by an equation; say their values are u and v, connected by an equation $F(u, v) = 0$; then, regarding u, v as the coordinates of a point *in plano*, this will be a point on the curve represented by the equation. The curve, in the widest sense of the expression, is the whole series of points, real or imaginary, the coordinates of which satisfy the equation, and these are exhibited by the foregoing corresponding figures in two planes; but in the ordinary sense the curve is the series of real points, with coordinates u, v, which satisfy the equation.

In geometry it is the curve, whether defined by means of its equation, or in any other manner, which is the subject for contemplation and study. But we also use the curve as a representation of its equation—that is, of the relation existing between two magnitudes x, y, which are taken as the coordinates of a point on the curve. Such employment of a curve for all sorts of purposes—the fluctuations of the barometer, the Cambridge boat races, or the Funds—is familiar to most of you. It is in like manner convenient in analysis, for exhibiting the relations between any three magnitudes x, y, z, to regard them as the coordinates of a point in space; and, on the like ground, we should at least wish to regard any four or more magnitudes as the coordinates of a point in space of a corresponding number of dimensions. Starting with the hypothesis of such a space, and of points therein each determined by means of its coordinates, it is found possible to establish a system of n-dimensional geometry analogous in every respect to our two- and three-dimensional geometries, and to a very considerable extent serving to exhibit the relations of the variables. To quote from my memoir 'On Abstract Geometry' (1869): 'The science presents itself in two ways: as a legitimate extension of the ordinary two- and three-dimensional geometries, and as a need in these geometries and in analysis generally. In fact, whenever we are concerned with quantities connected in any manner, and which are considered as variable or determinable, then the nature of the connection between the quantities is frequently rendered more intelligible by regarding them (if two or three in number) as the coordinates of a point in a plane or in space. For more than three quantities there is, from the greater complexity of the case, the greater need of such a representation; but this can only be obtained by means of the notion of a space of the proper dimensionality; and to use such representation we require a corresponding geometry. An important instance in plane

geometry has already presented itself in the question of the number of curves which satisfy given conditions; the conditions imply relations between the coefficients in the equation of the curve; and for the better understanding of these relations it was expedient to consider the coefficients as the coordinates of a point in a space of the proper dimensionality.'

It is to be borne in mind that the space, whatever its dimensionality may be, must always be regarded as an imaginary or complex space such as the two- or three-dimensional space of ordinary geometry; the advantages of the representation would otherwise altogether fail to be obtained.

I have spoken throughout of Cartesian coordinates; instead of these it is in plane geometry not unusual to employ trilinear coordinates, and these may be regarded as absolutely undetermined in their magnitude—viz. we may take x, y, z to be, not equal, but only proportional to the distances of a point from three given lines; the ratios of the coordinates (x, y, z) determine the point; and so in one-dimensional geometry, we may have a point determined by the ratio of its two coordinates x, y, these coordinates being proportional to the distances of the point from two fixed points; and generally in n-dimensional geometry a point will be determined by the ratios of the $(n+1)$ coordinates $(x, y, z \ldots)$. The corresponding analytical change is in the expression of the original magnitudes as fractions with a common denominator; we thus, in place of rational and integral non-homogeneous functions of the original variables, introduce rational and integral homogeneous functions (quantics) of the next succeeding number of variables—viz. we have binary quantics corresponding to one-dimensional geometry, ternary to two-dimensional geometry, and so on.

It is a digression, but I wish to speak of the representation of points or figures in space upon a plane. In perspective we represent a point in space by means of the intersection with the plane of the picture (suppose a pane of glass) of the line drawn from the point to the eye, and doing this for each point of the object we obtain a representation or picture of the object. But such representation is an imperfect one, as not determining the object: we cannot by means of the picture alone find out the form of the object; in fact, for a given point of the picture the corresponding point of the object is not a determinate point, but it is a point anywhere in the line joining the eye with the point of the picture. To determine the object we need two pictures, such as we have in a plan and elevation, or, what is the same thing, in a representation on the system of Monge's descriptive geometry. But it is theoretically more simple to consider two projections on the same plane, with different positions of the eye: the point in space is here represented on the plane by means of two points which are such that the line joining them passes through a fixed point of the plane (this point is in fact the intersection with

the plane of the picture of the line joining the two positions of the eye); the figure in space is thus represented on the plane by two figures, which are such that the lines joining corresponding points of the two figures pass always through the fixed point. And such two figures completely replace the figure in space; we can by means of them perform on the plane any constructions which could be performed on the figure in space, and employ them in the demonstration of properties relating to such figure. A curious extension has recently been made: two figures in space such that the lines joining corresponding points pass through a fixed point have been regarded by the Italian geometer Veronèse as representations of a figure in four-dimensional space, and have been used for the demonstration of properties of such figure.

I referred to the connection of Mathematics with the notions of space and time, but I have hardly spoken of time. It is, I believe, usually considered that the notion of number is derived from that of time; thus Whewell in the work referred to, p. xx, says number is a modification of the conception of repetition, which belongs to that of *time.* I cannot recognise that this is so: it seems to me that we have (independently, I should say, of space or time, and in any case not more depending on time than on space) the notion of plurality; we think of, say, the letters a, b, c, &c., and thence in the case of a finite set—for instance a, b, c, d, e—we arrive at the notion of number; coordinating them one by one with any other set of things, or, suppose, with the words first, second, &c., we find that the last of them goes with the word fifth, and we say that the number of things is = five: the notion of cardinal number would thus appear to be derived from that of ordinal number.

Questions of combination and arrangement present themselves, and it might be possible from the mere notion of plurality to develope a branch of mathematical science; this, however, would apparently be of a very limited extent, and it is difficult *not* to introduce into it the notion of number; in fact, in the case of a finite set of things, to avoid asking the question, How many? If we do this, we have a large enough subject, including the partition of numbers, which Sylvester has called Tactic.

From the notion thus arrived at of an integer number, we pass to that of a fractional number, and we see how by means of these the ratio of any two concrete magnitudes of the same kind can be expressed, not with absolute accuracy, but with any degree of accuracy we please: for instance, a length is so many feet, tenths of a foot, hundredths, thousandths, &c.; subdivide as you please, *non constat* that the length can be expressed accurately, we have in fact incommensurables; as to the part which these play in the Theory of Numbers, I shall have to speak presently: for the moment I am only concerned with them in so far as they show that we cannot from the notion of number pass to that which is required in analysis, the notion of an abstract (real and positive) magnitude susceptible of continuous variation. The difficulty is got over by a

postulate. We consider an abstract (real and positive) magnitude, and regard it as susceptible of continuous variation, without in anywise concerning ourselves about the actual expression of the magnitude by a numerical fraction or otherwise.

There is an interesting paper by Sir W. R. Hamilton, 'Theory of Conjugate Functions, or Algebraical Couples: with a preliminary and elementary Essay on Algebra as the Science of Pure Time,' 1833–35 (Trans. R. I. Acad. t. 17), in which, as appears by the title, he purposes to show that algebra is the science of pure time. He states there, in the General Introductory Remarks, his conclusions: first, that the notion of time is connected with existing algebra; second, that this notion or intuition of time may be unfolded into an independent pure science; and, third, that the science of pure time thus unfolded is coextensive and identical with algebra, so far as algebra itself is a science; and to sustain his first conclusion he remarks that 'the history of algebraic science shows that the most remarkable discoveries in it have been made either expressly through the notion of *time*, or through the closely connected (and in some sort coincident) notion of continuous progression. It is the genius of algebra to consider what it reasons upon as *flowing*, as it was the genius of geometry to consider what it reasoned on as *fixed*. . . . And generally the revolution which Newton made in the higher parts of both pure and applied algebra was founded mainly on the notion of *fluxion*, which involves the notion of *time*.' Hamilton uses the term algebra in a very wide sense, but whatever else he includes under it, he includes all that in contradistinction to the Differential Calculus would be called algebra. Using the word in this restricted sense, I cannot myself recognise the connection of algebra with the notion of time: granting that the notion of continuous progression presents itself, and is of importance, I do not see that it is in anywise the fundamental notion of the science. And still less can I appreciate the manner in which the author connects with the notion of time his algebraical couple, or imaginary magnitude $a + bi$ ($a + b\sqrt{-1}$, as written in the memoir).

I would go further: the notion of continuous variation is a very fundamental one, made a foundation in the Calculus of Fluxions (if not always so in the Differential Calculus) and presenting itself or implied throughout in mathematics: and it may be said that a change of any kind takes place only in time; it seems to me, however, that the changes which we consider in mathematics are for the most part considered quite irrespectively of time.

It appears to me that we do not have in Mathematics the notion of time until we bring it there: and that even in kinematics (the science of motion) we have very little to do with it; the motion is a hypothetical one; if the system be regarded as actually moving, the rate of motion is altogether undetermined and immaterial. The relative rates of motion of the different points of the system are nothing else than the ratios of purely geometrical quantities, the indefinitely short distances

simultaneously described, or which might be simultaneously described, by these points respectively. But whether the notion of time does or does not sooner enter into mathematics, we at any rate have the notion in Mechanics, and along with it several other new notions.

Regarding Mechanics as divided into Statics and Dynamics, we have in dynamics the notion of time, and in connection with it that of velocity: we have in statics and dynamics the notion of force; and also a notion which in its most general form I would call that of corpus: viz. this may be the material point or particle, the flexible inextensible string or surface, or the rigid body, of ordinary mechanics; the incompressible perfect fluid of hydrostatics and hydrodynamics; the ether of any undulatory theory; or any other imaginable corpus; for instance, one really deserving of consideration in any general treatise of mechanics is a developable or skew surface with absolutely rigid generating lines, but which can be bent about these generating lines, so that the element of surface between two consecutive lines rotates as a whole about one of them. We have besides, in dynamics necessarily, the notion of mass or inertia.

We seem to be thus passing out of pure mathematics into physical science; but it is difficult to draw the line of separation, or to say of large portions of the 'Principia,' and the 'Mécanique céleste,' or of the whole of the 'Mécanique analytique,' that they are not pure mathematics. It may be contended that we first come to physics when we attempt to make out the character of the corpus as it exists in nature. I do not at present speak of any physical theories which cannot be brought under the foregoing conception of mechanics.

I must return to the Theory of Numbers; the fundamental idea is here integer number: in the first instance positive integer number, but which may be extended to include negative integer number and zero. We have the notion of a product, and that of a prime number, which is not a product of other numbers; and thence also that of a number as the product of a determinate system of prime factors. We have here the elements of a theory in many respects analogous to algebra: an equation is to be solved—that is, we have to find the integer values (if any) which satisfy the equation; and so in other cases: the congruence notation, although of the very highest importance, does not affect the character of the theory.

But as already noticed we have incommensurables, and the consideration of these gives rise to a new universe of theory. We may take into consideration any surd number such as $\sqrt{2}$, and so consider numbers of the form $a + b\sqrt{2}$, (a and b any positive or negative integer numbers not excluding zero); calling these integer numbers, every problem which before presented itself in regard to integer numbers in the original and ordinary sense of the word presents itself equally in regard to integer numbers in this new sense of the word; of course all definitions must be altered accordingly: an ordinary integer, which is in the ordinary sense

of the word a prime number, may very well be the product of two integers of the form $a + b\sqrt{2}$, and consequently not a prime number in the new sense of the word. Among the incommensurables which can be thus introduced into the Theory of Numbers (and which was in fact *first* so introduced) we have the imaginary i of ordinary analysis: viz. we may consider numbers $a+bi$ (a and b ordinary positive or negative integers, not excluding zero), and, calling these integer numbers, establish in regard to them a theory analogous to that which exists for ordinary real integers. The point which I wish to bring out is that the imaginary i does not in the Theory of Numbers occupy a unique position, such as it does in analysis and geometry; it is in the Theory of Numbers one out of an indefinite multitude of incommensurables.

I said that I would speak to you, not of the utility of mathematics in any of the questions of common life or of physical science, but rather of the obligations of mathematics to these different subjects. The consideration which thus presents itself is in a great measure that of the history of the development of the different branches of mathematical science in connection with the older physical sciences, Astronomy and Mechanics: the mathematical theory is in the first instance suggested by some question of common life or of physical science, is pursued and studied quite independently thereof, and perhaps after a long interval comes in contact with it, or with quite a different question. Geometry and algebra must, I think, be considered as each of them originating in connection with objects or questions of common life—geometry, notwithstanding its name, hardly in the measurement of land, but rather from the contemplation of such forms as the straight line, the circle, the ball, the top (or sugar-loaf): the Greek geometers appropriated for the geometrical forms corresponding to the last two of these, the words σφαῖρα and κῶνος, our cone and sphere, and they extended the word cone to mean the complete figure obtained by producing the straight lines of the surface both ways indefinitely. And so algebra would seem to have arisen from the sort of easy puzzles in regard to numbers which may be made, either in the picturesque forms of the Bija-Ganita with its maiden with the beautiful locks, and its swarms of bees amid the fragrant blossoms, and the one queen-bee left humming around the lotus flower; or in the more prosaic form in which a student has presented to him in a modern text-book a problem leading to a simple equation.

The Greek geometry may be regarded as beginning with Plato (B.C. 430–347): the notions of geometrical analysis, loci, and the conic sections are attributed to him, and there are in his Dialogues many very interesting allusions to mathematical questions: in particular the passage in the 'Theætetus,' where he affirms the incommensurability of the sides of certain squares. But the earliest extant writings are those of Euclid (B.C. 285): there is hardly anything in mathematics more beautiful than his wondrous fifth book; and he has also in the seventh eighth,

ninth and tenth books fully and ably developed the first principles of the Theory of Numbers, including the theory of incommensurables. We have next Apollonius (about B.C. 247), and Archimedes (B.C. 287–212), both geometers of the highest merit, and the latter of them the founder of the science of statics (including therein hydrostatics): his dictum about the lever, his '*Εὕρηκα*,' and the story of the defence of Syracuse, are well known. Following these we have a worthy series of names, including the astronomers Hipparchus (B.C. 150) and Ptolemy (A.D. 125), and ending, say, with Pappus (A.D. 400), but continued by their Arabian commentators, and the Italian and other European geometers of the sixteenth century and later, who pursued the Greek geometry.

The Greek arithmetic was, from the want of a proper notation, singularly cumbrous and difficult; and it was for astronomical purposes superseded by the sexagesimal arithmetic, attributed to Ptolemy, but probably known before his time. The use of the present so-called Arabic figures became general among Arabian writers on arithmetic and astronomy about the middle of the tenth century, but was not introduced into Europe until about two centuries later. Algebra among the Greeks is represented almost exclusively by the treatise of Diophantus (A.D. 150), in fact a work on the Theory of Numbers containing questions relating to square and cube numbers, and other properties of numbers, with their solutions; this has no historical connection with the later algebra, introduced into Italy from the East by Leonardi Bonacci of Pisa (A.D. 1202–1208) and successfully cultivated in the fifteenth and sixteenth centuries by Lucas Paciolus, or de Burgo, Tartaglia, Cardan, and Ferrari. Later on, we have Vieta (1540–1603), Harriot, already referred to, Wallis, and others.

Astronomy is of course intimately connected with geometry; the most simple facts of observation of the heavenly bodies can only be *stated* in geometrical language: for instance, that the stars describe circles about the pole-star, or that the different positions of the sun among the fixed stars in the course of the year form a circle. For astronomical calculations it was found necessary to determine the arc of a circle by means of its chord: the notion is as old as Hipparchus, a work of whom is referred to as consisting of twelve books on the chords of circular arcs; we have (A.D. 125) Ptolemy's 'Almagest,' the first book of which contains a table of arcs and chords with the method of construction; and among other theorems on the subject he gives there the theorem afterwards inserted in Euclid (Book VI. Prop. D) relating to the rectangle contained by the diagonals of a quadrilateral inscribed in a circle. The Arabians made the improvement of using in place of the chord of an arc the sine, or half-chord of double the arc; and so brought the theory into the form in which it is used in modern trigonometry: the before-mentioned theorem of Ptolemy, or rather a particular case of it, translated into the notation of sines, gives the expression for the sine of the sum of two arcs in terms of the sines and cosines of the component arcs; and it is thus the

fundamental theorem on the subject. We have in the fifteenth and sixteenth centuries a series of mathematicians who with wonderful enthusiasm and perseverance calculated tables of the trigonometrical or circular functions, Purbach, Müller or Regiomontanus, Copernicus, Reinhold, Maurolycus, Vieta, and many others; the tabulations of the functions tangent and secant are due to Reinhold and Maurolycus respectively.

Logarithms were invented, not exclusively with reference to the calculation of trigonometrical tables, but in order to facilitate numerical calculations generally; the invention is due to John Napier of Merchiston, who died in 1618 at 67 years of age; the notion was based upon refined mathematical reasoning on the comparison of the spaces described by two points, the one moving with a uniform velocity, the other with a velocity varying according to a given law. It is to be observed that Napier's logarithms were nearly but not exactly those which are now called (sometimes Napierian, but more usually) hyperbolic logarithms—those to the base e; and that the change to the base 10 (the great step by which the invention was perfected for the object in view) was indicated by Napier but actually made by Henry Briggs, afterwards Savilian Professor at Oxford (d. 1630). But it is the hyperbolic logarithm which is mathematically important. The direct function e^x or exp. x, which has for its inverse the hyperbolic logarithm, presented itself, but not in a prominent way. Tables were calculated of the logarithms of numbers, and of those of the trigonometrical functions.

The circular functions and the logarithm were thus invented each for a practical purpose, separately and without any proper connection with each other. The functions are connected through the theory of imaginaries and form together a group of the utmost importance throughout mathematics: but this is mathematical theory; the obligation of mathematics is for the discovery of the functions.

Forms of spirals presented themselves in Greek architecture, and the curves were considered mathematically by Archimedes; the Greek geometers invented some other curves, more or less interesting, but recondite enough in their origin. A curve which might have presented itself to anybody, that described by a point in the circumference of a rolling carriage-wheel, was first noticed by Mersenne in 1615, and is the curve afterwards considered by Roberval, Pascal, and others under the name of the Roulette, otherwise the Cycloid. Pascal (1623–1662) wrote at the age of seventeen his 'Essais pour les Coniques' in seven short pages, full of new views on these curves, and in which he gives, in a paragraph of eight lines, his theorem of the inscribed hexagon.

Kepler (1571–1630) by his empirical determination of the laws of planetary motion, brought into connection with astronomy one of the forms of conic, the ellipse, and established a foundation for the theory of gravitation. Contemporary with him for most of his life, we have Galileo (1564–1642), the founder of the science of dynamics; and closely follow-

ing upon Galileo we have Isaac Newton (1643–1727): the 'Philosophiæ naturalis Principia Mathematica' known as the 'Principia' was first published in 1687.

The physical, statical, or dynamical questions which presented themselves before the publication of the 'Principia' were of no particular mathematical difficulty; but it is quite otherwise with the crowd of interesting questions arising out of the theory of gravitation, which, in becoming the subject of mathematical investigation, have contributed very much to the advance of mathematics. We have the problem of two bodies, or, what is the same thing, that of the motion of a particle about a fixed centre of force, for any law of force; we have also the (mathematically very interesting) problem of the motion of a body attracted to two or more fixed centres of force; then, next preceding that of the actual solar system—the problem of three bodies; this has ever been and is far beyond the power of mathematics, and it is in the lunar and planetary theories replaced by what is mathematically a different problem, that of the motion of a body under the action of a principal central force and a disturbing force: or (in one mode of treatment) by the problem of disturbed elliptic motion. I would remark that we have here an instance in which an astronomical fact, the observed slow variation of the orbit of a planet, has directly suggested a mathematical method, applied to other dynamical problems, and which is the basis of very extensive modern investigations in regard to systems of differential equations. Again, immediately arising out of the theory of gravitation, we have the problem of finding the attraction of a solid body of any given form upon a particle, solved by Newton in the case of a homogeneous sphere, but which is far more difficult in the next succeeding cases of the spheroid of revolution (very ably treated by Maclaurin) and of the ellipsoid of three unequal axes: there is perhaps no problem of mathematics which has been treated by as great a variety of methods, or has given rise to so much interesting investigation as this last problem of the attraction of an ellipsoid upon an interior or exterior point. It was a dynamical problem, that of vibrating strings, by which Lagrange was led to the theory of the representation of a function as the sum of a series of multiple sines and cosines; and connected with this we have the expansions in terms of Legendre's functions P_m, suggested to him by the question just referred to of the attraction of an ellipsoid; the subsequent investigations of Laplace on the attractions of bodies differing slightly from the sphere led to the functions of two variables called Laplace's functions. I have been speaking of ellipsoids, but the general theory is that of attractions, which has become a very wide branch of modern mathematics; associated with it we have in particular the names of Gauss, Lejeune-Dirichlet, and Green; and I must not omit to mention that the theory is now one relating to n-dimensional space. Another great problem of celestial mechanics, that of the motion of the earth about its centre of gravity, in the most

simple case, that of a body not acted upon by any forces, is a very interesting one in the mathematical point of view.

I may mention a few other instances where a practical or physical question has connected itself with the development of mathematical theory. I have spoken of two map-projections—the stereographic, dating from Ptolemy; and Mercator's projection, invented by Edward Wright about the year 1600: each of these, as a particular case of the orthomorphic projection, belongs to the theory of the geometrical representation of an imaginary variable. I have spoken also of perspective, and of the representation of solid figures employed in Monge's descriptive geometry. Monge, it is well known, is the author of the geometrical theory of the curvature of surfaces and of curves of curvature: he was led to this theory by a problem of earthwork; from a given area, covered with earth of uniform thickness, to carry the earth and distribute it over an equal given area, with the least amount of cartage. For the solution of the corresponding problem in solid geometry he had to consider the intersecting normals of a surface, and so arrived at the curves of curvature. (See his 'Mémoire sur les Déblais et les Remblais,' Mem. de l'Acad., 1781.) The normals of a surface are, again, a particular case of a doubly infinite system of lines, and are so connected with the modern theories of congruences and complexes.

The undulatory theory of light led to Fresnel's wave-surface, a surface of the fourth order, by far the most interesting one which had then presented itself. A geometrical property of this surface, that of having tangent planes each touching it along a plane curve (in fact, a circle), gave to Sir W. R. Hamilton the theory of conical refraction. The wave-surface is now regarded in geometry as a particular case of Kummer's quartic surface, with sixteen conical points and sixteen singular tangent planes.

My imperfect acquaintance as well with the mathematics as the physics prevents me from speaking of the benefits which the theory of Partial Differential Equations has received from the hydrodynamical theory of vortex motion, and from the great physical theories of heat, electricity, magnetism, and energy.

It is difficult to give an idea of the vast extent of modern mathematics. This word 'extent' is not the right one: I mean extent crowded with beautiful detail—not an extent of mere uniformity such as an objectless plain, but of a tract of beautiful country seen at first in the distance, but which will bear to be rambled through and studied in every detail of hillside and valley, stream, rock, wood, and flower. But, as for anything else, so for a mathematical theory—beauty can be perceived, but not explained. As for mere extent, I can perhaps best illustrate this by speaking of the dates at which some of the great extensions have been made in several branches of mathematical science.

As regards geometry, I have already spoken of the invention of the Cartesian coordinates (1637). This gave to geometers the whole series of geometric curves of higher order than the conic sections: curves of the third order, or cubic curves; curves of the fourth order, or quartic curves; and so on indefinitely. The first fruits of it were Newton's 'Enumeratio linearum tertii ordinis,' and the extremely interesting investigations of Maclaurin as to corresponding points on a cubic curve. This was at once enough to show that the new theory of cubic curves was a theory quite as beautiful and far more extensive than that of conics. And I must here refer to Euler's remark in the paper 'Sur une contradiction apparente dans la théorie des courbes planes' (Berlin Memoirs, 1748), in regard to the nine points of intersection of two cubic curves (viz. that when eight of the points are given the ninth point is thereby completely determined): this is not only a fundamental theorem in cubic curves (including in itself Pascal's theorem of the hexagon inscribed in a conic), but it introduces into plane geometry a new notion—that of the point-system, or system of the points of intersection of two curves.

A theory derived from the conic, that of polar reciprocals, led to the general notion of geometrical duality—viz. that in plane geometry the point and the line are correlative figures; and founded on this we have Plücker's great work, the 'Theorie der algebraischen Curven' (Bonn, 1839), in which he establishes the relation which exists between the order and class of a curve and the number of its different point- and line-singularities (Plücker's six equations). It thus appears that the true division of curves is not a division according to order only, but according to order and class, and that the curves of a given order and class are again to be divided into families according to their singularities: this is not a mere subdivision, but is really a widening of the field of investigation; each such family of curves is in itself a subject as wide as the totality of the curves of a given order might previously have appeared.

We *unite* families by considering together the curves of a given *Geschlecht*, or deficiency; and in reference to what I shall have to say on the Abelian functions, I must speak of this notion introduced into geometry by Riemann in the memoir 'Theorie der Abel'schen Functionen,' Crelle, t. 54 (1857). For a curve of a given order, reckoning cusps as double points, the deficiency is equal to the greatest number $\frac{1}{2}(n-1)(n-2)$ of the double points which a curve of that order can have, less the number of double points which the curve actually has. Thus a conic, a cubic with one double point, a quartic with three double points, &c., are all curves of the deficiency 0; the general cubic is a curve, and the most simple curve, of the deficiency 1; the general quartic is a curve of deficiency 3; and so on. The deficiency is usually represented by the letter p. Riemann considers the general question of the rational transformation of a plane curve: viz. here the coordinates, assumed to be homogeneous or trilinear, are replaced by any rational and integral

functions, homogeneous of the same degree in the new coordinates; the transformed curve is in general a curve of a different order, with its own system of double points; but the deficiency p remains unaltered; and it is on this ground that he unites together and regards as a single class the whole system of curves of a given deficiency p. It must not be supposed that all such curves admit of rational transformation the one into the other: there is the further theorem that any curve of the class depends, in the case of a cubic, upon one parameter, but for $p > 1$ upon $3p - 3$ parameters, each such parameter being unaltered by the rational transformation; it is thus only the curves having the same one parameter, or $3p - 3$ parameters, which can be rationally transformed the one into the other.

Solid geometry is a far wider subject: there are more theories, and each of them is of greater extent. The ratio is not that of the numbers of the dimensions of the spaces considered, or, what is the same thing, of the elementary figures—point and line in the one case; point, line and plane in the other case—belonging to these spaces respectively, but it is a very much higher one. For it is very inadequate to say that in plane geometry we have the curve, and in solid geometry the curve and surface: a more complete statement is required for the comparison. In plane geometry we have the curve, which may be regarded as a singly infinite system of points, and also as a singly infinite system of lines. In solid geometry we have, first, that which under one aspect is the curve, and under another aspect the developable, and which may be regarded as a singly infinite system of points, of lines, or of planes; secondly, the surface, which may be regarded as a doubly infinite system of points or of planes, and also as a special triply infinite system of lines (viz. the tangent-lines of the surface are a special complex): as distinct particular cases of the former figure, we have the plane curve and the cone; and as a particular case of the latter figure, the ruled surface or singly infinite system of lines; we have *besides* the congruence, or doubly infinite system of lines, and the complex, or triply infinite system of lines. But, even if in solid geometry we attend only to the curve and the surface, there are crowds of theories which have scarcely any analogues in plane geometry. The relation of a curve to the various surfaces which can be drawn through it, or of a surface to the various curves that can be drawn upon it, is different in kind from that which in plane geometry most nearly corresponds to it, the relation of a system of points to the curves through them, or of a curve to the points upon it. In particular, there is nothing in plane geometry corresponding to the theory of the curves of curvature of a surface. To the single theorem of plane geometry, a right line is the shortest distance between two points, there correspond in solid geometry two extensive and difficult theories—that of the geodesic lines upon a given surface, and that of the surface of minimum area for any given boundary. Again, in solid geometry we have the interesting and difficult question of the representation of a curve by means of

equations; it is not every curve, but only a curve which is the complete intersection of two surfaces, which can be properly represented by two equations $(x, y, z, w)^m = 0$, $(x, y, z, w)^n = 0$, in quadriplanar coordinates; and in regard to this question, which may also be regarded as that of the classification of curves in space, we have quite recently three elaborate memoirs by Nöther, Halphen, and Valentiner respectively.

In n-dimensional geometry, only isolated questions have been considered. The field is simply too wide; the comparison with each other of the two cases of plane geometry and solid geometry is enough to show how the complexity and difficulty of the theory would increase with each successive dimension.

In Transcendental Analysis, or the Theory of Functions, we have all that has been done in the present century with regard to the general theory of the function of an imaginary variable by Gauss, Cauchy, Puiseux, Briot, Bouquet, Liouville, Riemann, Fuchs, Weierstrass, and others. The fundamental idea of the geometrical representation of an imaginary variable $x + iy$, by means of the point having x, y for its coordinates, belongs, as I mentioned, to Gauss; of this I have already spoken at some length. The notion has been applied to differential equations; in the modern point of view, the problem in regard to a given differential equation is, not so much to reduce the differential equation to quadratures, as to determine from it directly the course of the integrals for all positions of the point representing the independent variable: in particular, the differential equation of the second order leading to the hypergeometric series $F(\alpha, \beta, \gamma, x)$ has been treated in this manner, with the most interesting results; the function so determined for all values of the parameters (α, β, γ) is thus becoming a known function. I would here also refer to the new notion in this part of analysis introduced by Weierstrass—that of the one-valued integer function, as defined by an infinite series of ascending powers, convergent for all finite values, real or imaginary, of the variable x or $1/x - c$, and so having the one essential singular point $x = \infty$ or $x = c$, as the case may be: the memoir is published in the Berlin Abhandlungen, 1876.

But it is not only general theory: I have to speak of the various special functions to which the theory has been applied, or say the various known functions.

For a long time the only known transcendental functions were the circular functions sine, cosine, &c.; the logarithm—*i.e.* for analytical purposes the hyperbolic logarithm to the base e; and, as implied therein, the exponential function e^x. More completely stated, the group comprises the direct circular functions sin, cos, &c.; the inverse circular functions $\sin^{-1}$ or arcsin, &c.; the exponential function, exp.; and the inverse exponential, or logarithmic, function, log.

Passing over the very important Eulerian integral of the second kind or gamma-function, the theory of which has quite recently given

rise to some very interesting developments—and omitting to mention at all various functions of minor importance,—we come (1811–1829) to the very wide groups, the elliptic functions and the single theta-functions. I give the interval of date so as to include Legendre's two systematic works, the 'Exercises de Calcul Intégral' (1811–1816) and the 'Théorie des Fonctions Elliptiques' (1825–1828); also Jacobi's 'Fundamenta nova theoriæ Functionum Ellipticarum' (1829), calling to mind that many of Jacobi's results were obtained simultaneously by Abel. I remark that Legendre started from the consideration of the integrals depending on a radical $\sqrt{X}$, the square root of a rational and integral quartic function of a variable x; for this he substituted a radical $\Delta\phi, = \sqrt{1-k^2\sin^2\phi}$, and he arrived at his three kinds of elliptic integrals $F\phi$, $E\phi$, $\Pi\phi$, depending on the argument or amplitude ϕ, the modulus k, and also the last of them on a parameter n; the function F is properly an inverse function, and in place of it Abel and Jacobi each of them introduced the direct functions corresponding to the circular functions sine and cosine, Abel's functions called by him ϕ, f, F, and Jacobi's functions sinam, cosam, Δam, or as they are also written sn, cn, dn. Jacobi, moreover, in the development of his theory of transformation obtained a multitude of formulæ containing q, a transcendental function of the modulus defined by the equation $q = e^{-\pi K'/K}$, and he was also led by it to consider the two new functions H, Θ, which (taken each separately with two different arguments) are in fact the four functions called elsewhere by him Θ_1, Θ_2, Θ_3, Θ_4; these are the so-called theta-functions, or, when the distinction is necessary, the single theta-functions. Finally, Jacobi using the transformation $\sin\phi = \text{sinam}\, u$, expressed Legendre's integral of the second and third kinds as integrals depending on the new variable u, denoting them by means of the letters Z, Π, and connecting them with his own functions H and Θ: and the elliptic functions sn, cn, dn are expressed with these, or say with Θ_1, Θ_2, Θ_3, Θ_4, as fractions having a common denominator.

It may be convenient to mention that Hermite in 1858, introducing into the theory in place of q the new variable ω connected with it by the equation $q = e^{i\pi\omega}$ (so that ω is in fact $= iK'/K$), was led to consider the three functions $\phi\omega$, $\psi\omega$, $\chi\omega$, which denote respectively the values of $\sqrt[4]{k}$, $\sqrt[4]{k'}$ and $\sqrt[12]{kk'}$ regarded as functions of ω. A theta-function, putting the argument $= 0$, and then regarding it as a function of ω, is what Professor Smith in a valuable memoir, left incomplete by his death, calls an omega-function, and the three functions $\phi\omega$, $\psi\omega$, $\chi\omega$ are his modular functions.

The proper elliptic functions sn, cn, dn form a system very analogous to the circular functions sine and cosine (say they are a sine and two separate cosines), having a like addition-theorem, viz. the form of this theorem is that the sn, cn and dn of $x+y$ are each of them expressible rationally in terms of the sn, cn and dn of x and of the sn, cn and dn of y; and in fact reducing itself to the system of the circular functions in the particular case $k=0$. But there is the important difference of form that the expressions for the sn, cn and

dn of $x+y$ are fractional functions having a common denominator: this is a reason for regarding these functions as the ratios of four functions A, B, C, D, the absolute magnitudes of which are and remain indeterminate (the functions sn, cn, dn are in fact quotients $[\Theta_1, \Theta_2, \Theta_3] \div \Theta_4$ of the four theta-functions, but this is a further result in nowise deducible from the addition-equations, and which is intended to be for the moment disregarded; the remark has reference to what is said hereafter as to the Abelian functions). But there is in regard to the functions sn, cn, dn (what has no analogue for the circular functions), the whole theory of transformation of any order n prime or composite, and, as parts thereof, the whole theory of the modular and multiplier equations; and this theory of transformation spreads itself out in various directions, in geometry, in the Theory of Equations, and in the Theory of Numbers. Leaving the theta-functions out of consideration, the theory of the proper elliptic functions sn, cn, dn is at once seen to be a very wide one.

I assign to the Abelian functions the date 1826–1832. Abel gave what is called his theorem in various forms, but in its most general form in the 'Mémoire sur une propriété générale d'une classe très-étendue de Fonctions Transcendentes' (1826), presented to the French Academy of Sciences, and crowned by them after the author's death, in the following year. This is in form a theorem of the integral calculus, relating to integrals depending on an irrational function y determined as a function of x by any algebraical equation $F(x, y) = 0$ whatever: the theorem being that a sum of any number of such integrals is expressible by means of the sum of a determinate number p of like integrals, this number p depending on the form of the equation $F(x, y) = 0$ which determines the irrational y (to fix the ideas, remark that considering this equation as representing a curve, then p is really the deficiency of the curve; but as already mentioned, the notion of deficiency dates only from 1857): thus in applying the theorem to the case where y is the square root of a function of the fourth order, we have in effect Legendre's theorem for elliptic integrals $F\phi + F\psi$ expressed by means of a single integral $F\mu$, and not a theorem applying in form to the elliptic functions sn, cn, dn. To be intelligible I must recall that the integrals belonging to the case where y is the square root of a rational and integral function of an order exceeding four are (in distinction from the general case) termed hyperelliptic integrals: viz., if the order be 5 or 6, then these are of the class $p=2$; if the order be 7 or 8, then they are of the class $p=3$, and so on; the *general* Abelian integral of the class $p=2$ is a hyperelliptic integral: but if $p=3$, or any greater value, then the hyperelliptic integrals are only a particular case of the Abelian integrals of the same class. The further step was made by Jacobi in the short but very important memoir 'Considerationes generales de transcendentibus Abelianis,' Crelle, t. ix. (1832): viz. he there shows for the hyperelliptic integrals of any class (but the conclusion may be stated generally) that the direct functions to which Abel's theorem has reference are not functions of a

single variable, such as the elliptic sn, cn, or dn, but functions of p variables. Thus, in the case $p=2$, which Jacobi specially considers, it is shown that Abel's theorem has reference to two functions $\lambda(u, v)$, $\lambda_1(u, v)$ each of two variables, and gives in effect an addition-theorem for the expression of the functions $\lambda(u+u', v+v')$, $\lambda_1(u+u', v+v')$ algebraically in terms of the functions $\lambda(u, v)$, $\lambda_1(u, v)$, $\lambda(u', v')$, $\lambda_1(u', v')$.

It is important to remark that Abel's theorem does not directly give, nor does Jacobi assert that it gives, the addition-theorem in a perfect form. Take the case $p=1$: the result from the theorem is that we have a function $\lambda(u)$, which is such that $\lambda(u+v)$ can be expressed algebraically in terms of $\lambda(u)$ and $\lambda(v)$. This is of course perfectly correct, $\text{sn}(u+v)$ is expressible algebraically in terms of $\text{sn}\,u$, $\text{sn}\,v$, but the expression involves the radicals $\sqrt{1-\text{sn}^2 u}$, $\sqrt{1-k^2\text{sn}^2 u}$, $\sqrt{1-\text{sn}^2 v}$, $\sqrt{1-k^2\text{sn}^2 v}$; but it does not give the three functions sn, cn, dn, or in anywise amount to the statement that the sn, cn and dn u of $u+v$ are expressible rationally in terms of the sn, cn and dn of u and of v. In the case $p=1$, the right number of functions, each of one variable, is 3, but the three functions sn, cn and dn are properly considered as the ratios of 4 functions; and so, in general, the right number of functions, each of p variables, is 4^p-1, and these may be considered as the ratios of 4^p functions. But notwithstanding this last remark, it may be considered that the notion of the Abelian functions of p variables is established, and the addition-theorem for these functions in effect given by the memoirs (Abel 1826, Jacobi 1832) last referred to.

We have next for the case $p=2$, which is hyperelliptic, the two extremely valuable memoirs, Göpel, 'Theoria transcendentium Abelianarum primi ordinis adumbratio læva,' Crelle, t. xxxv. (1847), and Rosenhain, 'Mémoire sur les fonctions de deux variables et à quatre périodes qui sont les inverses des intégrales ultra-elliptiques de la première classe' (1846), Paris, Mém. Savans Étrang. t. xi. (1851), each of them establishing on the analogy of the single theta-functions the corresponding functions of two variables, or double theta-functions, and in connection with them the theory of the Abelian functions of two variables. It may be remarked that in order of simplicity the theta-functions certainly precede the Abelian functions.

Passing over some memoirs by Weierstrass which refer to the general hyperelliptic integrals, p any value whatever, we come to Riemann, who died 1866, at the age of forty: collected edition of his works, Leipzig, 1876. His great memoir on the Abelian and theta-functions is the memoir already incidentally referred to, 'Theorie der Abel'schen Functionen,' Crelle, t. 54 (1857); but intimately connected therewith we have his Inaugural Dissertation (Göttingen, 1851), 'Grundlagen für eine allgemeine Theorie der Functionen einer veränderlichen Complexen-Grösse': his treatment of the problem of the Abelian functions, and establishment for the purpose of this theory of the multiple theta-functions, are alike founded on his general principles of the theory of the functions of a variable complex

magnitude $x + iy$, and it is this which would have to be gone into for any explanation of his method of dealing with the problem.

Riemann, starting with the integrals of the most general form, and considering the inverse functions corresponding to these integrals—that is, the Abelian functions of p variables—defines a theta-function of p variables, or p-tuple theta-function, as the sum of a p-tuply infinite series of exponentials, the general term of course depending on the p variables; and he shows that the Abelian functions are algebraically connected with theta-functions of the proper arguments. The theory is presented in the broadest form; in particular as regards the theta-functions, the 4^p functions are not even referred to, and there is no development as to the form of the algebraic relations between the two sets of functions.

In the Theory of Equations, the beginning of the century may be regarded as an epoch. Immediately preceding it, we have Lagrange's 'Traité des Equations Numériques' (1st ed. 1798), the notes to which exhibit the then position of the theory. Immediately following it, the great work by Gauss, the 'Disquisitiones Arithmeticæ' (1801), in which he establishes the theory for the case of a prime exponent n, of the binomial equation $x^n - 1 = 0$: throwing out the factor $x - 1$, the equation becomes an equation of the order $n - 1$, and this is decomposed into equations the orders of which are the prime factors of $n - 1$. In particular, Gauss was thereby led to the remarkable geometrical result that it was possible to construct geometrically—that is, with only the ruler and compass—the regular polygons of 17 sides and 257 sides respectively. We have then (1826–1829) Abel, who, besides his demonstration of the impossibility of the solution of a quintic equation by radicals, and his very important researches on the general question of the algebraic solution of equations, established the theory of the class of equations since called Abelian equations. He applied his methods to the problem of the division of the elliptic functions, to (what is a distinct question) the division of the complete functions, and to the very interesting special case of the leminiscate. But the theory of algebraic solutions in its most complete form was established by Galois (born 1811, killed in a duel 1832), who for this purpose introduced the notion of a group of substitutions; and to him also are due some most valuable results in relation to another set of equations presenting themselves in the theory of elliptic functions—viz. the modular equations. In 1835 we have Jerrard's transformation of the general quintic equation. In 1870 an elaborate work, Jordan's 'Traité des Substitutions et des Equations algébriques:' a mere inspection of the table of contents of this would serve to illustrate my proposition as to the great extension of this branch of mathematics.

The Theory of Numbers was, at the beginning of the century, represented by Legendre's 'Théorie des Nombres' (1st ed. 1798), shortly followed by Gauss's 'Disquisitiones Arithmeticæ' (1801). This work by Gauss is,

throughout, a theory of ordinary real numbers. It establishes the notion of a congruence; gives a proof of the theorem of reciprocity in regard to quadratic residues; and contains a very complete theory of binary quadratic forms $(a, b, c)(x, y)^2$, of negative and positive determinant, including the theory, there first given, of the composition of such forms. It gives also the commencement of a like theory of ternary quadratic forms. It contains also the theory already referred to, but which has since influenced in so remarkable a manner the whole theory of numbers—the theory of the solution of the binomial equation $x^n - 1 = 0$: it is, in fact, the roots or periods of roots derived from these equations which form the incommeasurables, or unities, of the complex theories which have been chiefly worked at; thus, the i of ordinary analysis presents itself as a root of the equation $x^4 - 1 = 0$. It was Gauss himself who, for the development of a real theory—that of biquadratic residues—found it necessary to use complex numbers of the before-mentioned form, $a + bi$ (a and b positive or negative real integers, including zero), and the theory of these numbers was studied and cultivated by Lejeune-Dirichlet. We have thus a new theory of these complex numbers, side by side with the former theory of real numbers: everything in the real theory reproducing itself, prime numbers, congruences, theories of residues, reciprocity, quadratic forms, &c., but with greater variety and complexity, and increased difficulty of demonstration. But instead of the equation $x^4 - 1 = 0$, we may take the equation $x^3 - 1 = 0$: we have here the complex numbers $a + b\rho$ composed with an imaginary cube root of unity, the theory specially considered by Eisenstein: again a new theory, corresponding to but different from that of the numbers $a + bi$. The general case of any prime value of the exponent n, and with periods of roots, which here present themselves instead of single roots, was first considered by Kummer: viz. if $n - 1 = ef$, and $\eta_1, \eta_2 \ldots \eta_e$ are the e periods, each of them a sum of f roots, of the equation $x^n - 1 = 0$, then the complex numbers considered are the numbers of the form $a_1 \eta_1 + a_2 \eta_2 \ldots + a_e\eta_e$ ($a_1, a_2 \ldots a_e$ positive or negative ordinary integers, including zero): f may be $= 1$, and the theory for the periods thus includes that for the single roots.

We have thus a new and very general theory, including within itself that of the complex numbers $a+bi$ and $a+b\rho$. But a new phenomenon presents itself; for these special forms the properties in regard to prime numbers corresponded precisely with those for real numbers; a non-prime number was in one way only a product of prime factors; the power of a prime number has only factors which are lower powers of the same prime number: for instance, if p be a prime number, then, excluding the obvious decomposition $p.\,p^2$, we cannot have $p^3 =$ a product of two factors A, B. In the general case this is not so, but the exception first presents itself for the number 23; in the theory of the numbers composed with the 23rd roots of unity, we have prime numbers p, such that $p^3 = \text{AB}$. To restore the theorem, it is necessary to establish the notion of ideal numbers; a prime

number p is by definition not the product of two actual numbers, but in the example just referred to the number p is the product of two ideal numbers having for their cubes the two actual numbers A, B, respectively, and we thus have $p^3=AB$. It is, I think, in this way that we most easily get some notion of the meaning of an ideal number, but the mode of treatment (in Kummer's great memoir, 'Ueber die Zerlegung der aus Wurzeln der Einheit gebildeten Complexen-Zahlen in ihre Primfactoren, Crelle, t. xxxv. 1847) is a much more refined one; an ideal number, without ever being isolated, is made to manifest itself in the properties of the prime number of which it is a factor, and without reference to the theorem afterwards arrived at, that there is always some power of the ideal number which is an actual number. In the still later developments of the Theory of Numbers by Dedekind, the units, or incommensurables, are the roots of any irreducible equation having for its coefficients ordinary integer numbers, and with the coefficient unity for the highest power of x. The question arises, What is the analogue of a whole number? thus for the very simple case of the equation $x^2+3=0$, we have as a whole number the apparently fractional form $\frac{1}{2}(1+i\sqrt{3})$ which is the imaginary cube root of unity, the ρ of Eisenstein's theory. We have, moreover, the (as far as appears) wholly distinct complex theory of the numbers composed with the congruence-imaginaries of Galois: viz. these are imaginary numbers assumed to satisfy a congruence which is not satisfied by any real number; for instance the congruence $x^2-2=0$ (mod 5) has no real root, but we assume an imaginary root i, the other root is then $=-i$, and we then consider the system of complex numbers $a+bi$ (mod 5), viz. we have thus the 5^2 numbers obtained by giving to each of the numbers a, b, the values 0, 1, 2, 3, 4, successively. And so in general, the consideration of an irreducible congruence $F(x)=0$ (mod p.) of the order n, to any prime modulus p, gives rise to an imaginary congruence root i, and to complex numbers of the form $a+bi+ci^2\cdots+ki^{n-1}$, where a, b, ... k are ordinary integers each $=0, 1, 2, \cdots p-1$.

As regards the theory of forms, we have in the ordinary theory, in addition to the binary and ternary quadratic forms, which have been very thoroughly studied, the quaternary and higher quadratic forms (to these last belong as very particular cases the theories of the representation of a number as a sum of four, five or more squares), and also binary cubic and quartic forms, and ternary cubic forms, in regard to all which something has been done; the binary quadratic forms have been studied in the theory of the complex numbers $a+bi$.

A seemingly isolated question in the Theory of Numbers, the demonstration of Fermat's theorem of the impossibility for any exponent λ greater than 3, of the equation $x^\lambda+y^\lambda=z^\lambda$, has given rise to investigations of very great interest and difficulty.

Outside of ordinary mathematics, we have some theories which must be referred to: algebraical, geometrical, logical. It is, as in many other

cases, difficult to draw the line; we do in ordinary mathematics use symbols not denoting quantities, which we nevertheless combine in the way of addition and multiplication, $a+b$, and ab, and which may be such as not to obey the commutative law $ab = ba$, in particular this is or may be so in regard to symbols of operation; and it could hardly be said that any development whatever of the theory of such symbols of operation did not belong to ordinary algebra. But I do separate from ordinary mathematics the system of multiple algebra or linear associative algebra, developed in the valuable memoir by the late Benjamin Peirce, 'Linear Associative Algebra' (1870, reprinted 1881 in the American Journal of Mathematics, vol. iv. with notes and addenda by his son, C. S. Peirce); we here consider symbols A, B, &c. which are linear functions of a determinate number of letters or units i, j, k, l, &c., with coefficients which are ordinary analytical magnitudes, real or imaginary (viz. the coefficients are in general of the form $x + iy$, where i is the before-mentioned imaginary or $\sqrt{-1}$ of ordinary analysis). The letters i, j, &c., are such that every binary combination i^2, ij, ji, &c. (the ij being in general not $= ji$), is equal to a linear function of the letters, but under the restriction of satisfying the associative law: viz. for each combination of three letters $ij.k$ is $= i.jk$, so that there is a determinate and unique product of three or more letters; or, what is the same thing, the laws of combination of the units i, j, k, are defined by a multiplication table giving the values of i^2, ij, ji, &c.; the original units may be replaced by linear functions of these units, so as to give rise, for the units finally adopted, to a multiplication table of the most simple form; and it is very remarkable, how frequently in these simplified forms we have nilpotent or idempotent symbols ($i^2 = 0$, or $i^2 = i$ as the case may be), and symbols i, j, such that $ij = ji = 0$; and consequently how simple are the forms of the multiplication tables which define the several systems respectively.

I have spoken of this multiple algebra before referring to various geometrical theories of earlier date, because I consider it as the general analytical basis, and the true basis, of these theories. I do not realise to myself directly the notions of the addition or multiplication of two lines, areas, rotations, forces, or other geometrical, kinematical, or mechanical entities; and I would formulate a general theory as follows: consider any such entity as determined by the proper number of parameters a, b, c, (for instance, in the case of a finite line given in magnitude and position, these might be the length, the coordinates of one end, and the direction-cosines of the line considered as drawn from this end); and represent it by or connect it with the linear function $ai + bj + ck +$ &c. formed with these parameters as coefficients, and with a given set of units, i, j, k, &c. Conversely, any such linear function represents an entity of the kind in question. Two given entities are represented by two linear functions; the sum of these is a like linear function representing an entity of the same kind, which may be regarded as the sum of the two entities; and the product of them (taken in a determined order, when

the order is material) is an entity of the same kind, which may be regarded as the product (in the same order) of the two entities. We thus establish by definition the notion of the sum of the two entities, and that of the product (in a determinate order, when the order is material) of the two entities. The value of the theory in regard to any kind of entity would of course depend on the choice of a system of units, i, j, k . . with such laws of combination as would give a geometrical or kinematical or mechanical significance to the notions of the sum and product as thus defined.

Among the geometrical theories referred to, we have a theory (that of Argand, Warren, and Peacock) of imaginaries in plane geometry; Sir W. R. Hamilton's very valuable and important theory of Quaternions; the theories developed in Grassmann's 'Ausdehnungslehre,' 1841 and 1862; Clifford's theory of Biquaternions, and recent extensions of Grassmann's theory to non-Euclidian space, by Mr. Homersham Cox. These different theories have of course been developed, not in anywise from the point of view in which I have been considering them, but from the points of view of their several authors respectively.

The literal symbols x, y, &c., used in Boole's 'Laws of Thought' (1854), to represent things as subjects of our conceptions, are symbols obeying the laws of algebraic combination (the distributive, commutative, and associative laws) but which are such that for any one of them, say x, we have $x-x^2=0$, this equation not implying (as in ordinary algebra it would do) either $x=0$ or else $x=1$. In the latter part of the work relating to the Theory of Probabilities there is a difficulty in making out the precise meaning of the symbols, and the remarkable theory there developed has, it seems to me, passed out of notice, without having been properly discussed. A paper by the same author, 'Of Propositions numerically definite' ('Camb. Phil. Trans.' 1869) is also on the borderland of logic and mathematics. It would be out of place to consider other systems of mathematical logic, but I will just mention that Mr. C. S. Peirce in his 'Algebra of Logic' (American Math. Journal, vol. iii.) establishes a notation for relative terms, and that these present themselves in connection with the systems of units of the linear associative algebra.

Connected with logic, but primarily mathematical and of the highest importance, we have Schubert's 'Abzählende Geometrie' (1878). The general question is, How many curves or other figures are there which satisfy given conditions? for example, How many conics are there which touch each of five given conics? The class of questions, in regard to the conic was first considered by Chasles, and we have his beautiful theory of the characteristics μ, ν, of the conics which satisfy four given conditions; questions relating to cubics and quartics were afterwards considered by Maillard and Zeuthen; and in the work just referred to the theory has become a very wide one. The noticeable point is that the symbols used by Schubert are in the first instance, not numbers, but mere logical symbols: for example, a letter g denotes the condition that a line shall cut

a given line ; g^2 that it shall cut each of two given lines ; and so in other cases ; and these logical symbols are combined together by algebraical laws : they first acquire a numerical signification when the number of conditions becomes equal to the number of parameters upon which the figure in question depends.

In all that I have last said in regard to theories outside of ordinary mathematics, I have been still speaking on the text of the vast extent of modern mathematics. In conclusion I would say that mathematics have steadily advanced from the time of the Greek geometers. Nothing is lost or wasted ; the achievements of Euclid, Archimedes, and Apollonius are as admirable now as they were in their own days. Descartes' method of co-ordinates is a possession for ever. But mathematics have never been cultivated more zealously and diligently, or with greater success, than in this century—in the last half of it, or at the present time : the advances made have been enormous, the actual field is boundless, the future full of hope. In regard to pure mathematics we may most confidently say :—

> Yet I doubt not through the ages one increasing purpose runs,
> And the thoughts of men are widened with the process of the suns.

REPORTS

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Report of the Committee, consisting of Professor G. CAREY FOSTER, Sir WILLIAM THOMSON, Professor AYRTON, Mr. J. PERRY, Professor W. G. ADAMS, Lord RAYLEIGH, Professor JENKIN, Dr. O. J. LODGE, Dr. JOHN HOPKINSON, Dr. A. MUIRHEAD (*Secretary*), Mr. W. H. PREECE, Mr. HERBERT TAYLOR, Professor EVERETT, Professor SCHUSTER, Sir W. SIEMENS, Dr. J. A. FLEMING, Professor G. F. FITZGERALD, Mr. R. T. GLAZEBROOK, *and* Professor CHRYSTAL, *appointed for the purpose of constructing and issuing practical Standards for use in Electrical Measurements.*

THE Committee report that, in accordance with suggestions made at the last meeting of the British Association, arrangements have now been completed for testing resistance coils at the Cavendish Laboratory and issuing certificates of their value. These arrangements have been made by Lord Rayleigh and Mr. Glazebrook, and the report contains an account by the latter of the methods employed and the conditions under which the testing is undertaken, in order that those who use such coils may have a more exact estimate of the value of the test.

The standards at the laboratory belonging to the Association, the values of which have been recently tested, are all single units. The best of these were all compared among themselves, originally by Hockin ('British Association Report,' 1867), and again by Chrystal and Saunder (Report, 1876), and more recently, at various temperatures between about 0° C. and 25° C. by Mr. Fleming in 1879–1881, and a chart has been constructed, from which the resistance of any one coil at a given temperature between these limits can be determined. On this chart a curve is drawn for each coil; the ordinates of the curve represent resistances, while the abscissæ give the temperatures. The temperatures at which the various resistances were originally each one B. A. Unit are known for the respective coils. For these temperatures the ordinates of the curves drawn ought to be the same, and the corresponding resistance one B. A. Unit. Mr. Fleming finds, however, that this is not the case. The resistances of the eight coils examined at the temperatures at which they were

originally said to be correct are slightly different. The greatest difference is that between the coils marked C and G, and amounts to ·0011 mean B. A. Unit.

The mean of all these resistances at the respective temperatures is taken as the mean B. A. Unit, and is that to which the resistance coils sent for testing are referred.

The coils examined are those marked as below in previous reports.

A	B	C	D	E	F	G	Flat	1876
2	3	58	35	36	29	43	Flat	1867

In comparing the single unit coils the form of resistance bridge devised by Mr. Fleming and described by him ('Proceedings of the Physical Society,' vol. iii.) is employed.

The bridge, with battery, keys and a suitable galvanometer, is permanently fitted up in a ground-floor room with a north aspect. The standard coils are kept in a case in the same room, and the baths in which the coils are to be immersed are always ready filled with water, which is thus at the temperature of the room.

When a coil is to be tested, a suitable standard is chosen, and the two are placed in the water baths and left at least three or four hours—more usually over night. The comparison is then made in the ordinary manner by Professor Carey Foster's method,[1] and the coils again left for some time without being removed from the water. After this second interval another comparison is made. The temperatures of the water baths are taken at each comparison, and as a rule differ very slightly.

We thus have two values of the resistance of the coil to be tested at two slightly different temperatures.

The mean of these will be the resistance of the coil in question at the mean of the two temperatures.

We are thus able to issue a certificate in the following form:—'This is to certify that the coil No. X has been compared with the British Association Standards, and that its value at a temperature of $A°$ C. is P B. A. Units or P' R. ohms; 1 B. A. Unit being ·9867 R. ohms.' We further propose to stamp all coils in the future with this monogram and a reference number.

One single unit coil by Messrs. Latimer Clark, Muirhead, & Co., three by Messrs. Elliott Brothers, for Professor Mascart, and one by Messrs. Simmons & Co., have been tested.

It will be noticed that nothing is said about the temperature coefficient of the coil or the temperature at which the coil is accurately 1 B. A. Unit. To determine this exactly is a somewhat long and troublesome operation, but at the same time it is one which every electrician, if he knows the value of the coil at one given temperature, can perform for himself with ordinary testing apparatus. It does not require the use of the standards. For many purposes the approximate value of the temperature coefficient obtained from a knowledge of the material of the coil will suffice; we may feel certain that anyone requiring greater accuracy would be quite able, and would prefer, to make the measure-

[1] *Journal of Soc. of Telegraph Engineers*, 1874.

ment himself. We can state with the very highest exactness that the resistance of the coil X at a temperature $A°$ C. is R. To obtain the temperature coefficient accurately requires an amount of labour which may be quite unnecessary for the purpose for which the coil is to be used.

But it is requisite to have standards of higher value than one unit, and part of the Association grant has been used in obtaining coils of a resistance of 10, 100, 10,00 and 100,00 units. Two of each value have been purchased, so that by frequent comparison of one with the other any accident to either may be checked.

It remains, therefore, to describe how these coils are to be referred to the standards. For the 10 units two methods have been adopted.

There are at the Cavendish Laboratory two five-unit coils. Each of these was compared with five single units placed in series, using Fleming's bridge to make the comparison, and the ten-unit coil was compared with these two in series.

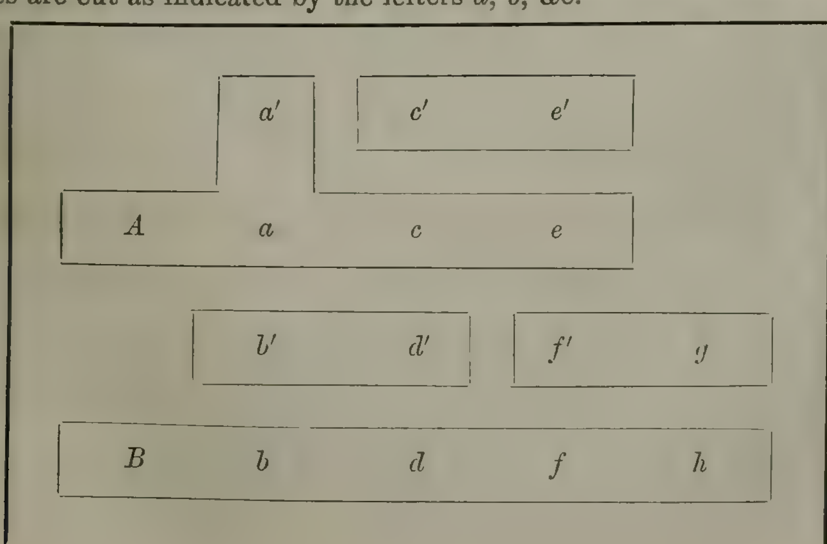
The values obtained by two observers at a temperature of 12° were:—

9·98360 . . . . Lord Rayleigh.
9·98393 . . . . R. T. G.

For the second method, suppose we have three coils each of resistance about 3 units. Let there be $3 + \alpha$, $3 + \beta$ and $3 + \gamma$, then the resistance of the three in series is $9 + \alpha + \beta + \gamma$, and in multiple arc, if we neglect terms like $\alpha^2 \frac{1}{81}$, &c., it is $1 + \frac{1}{9}(\alpha + \beta + \gamma)$, thus neglecting terms such as $\alpha^2 \frac{1}{9}$, the resistance of the three in series is just 9 times that of the three in multiple arc.

But the three coils in multiple arc are very nearly one unit, and can be compared with the standards. If then we combine in series with the same three one of the standards we have a resistance of approximately ten units, whose value is very accurately known, and with which any other ten-unit coil can be compared by the aid of Fleming's bridge. Lord Rayleigh has devised an arrangement of mercury cups, by means of which the changes indicated can be easily performed.

The three 3-unit coils are wound on the same bobbin, and inclosed in the same case. The six electrodes project in pairs, and their ends lie in a plane. The figure represents a piece of ebonite, through which, holes are cut as indicated by the letters a, b, &c.



On the under side of the ebonite, strong strips of copper, with their faces well amalgamated, are screwed, forming with the holes in the ebonite a series of cups, which are filled with mercury.

The copper strips are cut, as shown in the figure, to make the necessary connexions. The distances between the holes is such that the electrodes of the three coils respectively fit into *a b*, *c d*, and *e f*, or into *a′ b′*, *c′ d′*, and *e′ f′*.

Connexion is made with the bridge by means of the cups *A*, *B*, while the electrodes of the second single unit coil fit into *g* and *h*. In the first position the three coils are in multiple arc, as will be seen from the figure, and can be compared with a single unit, while in the second they are in series with the other single unit, and can be compared with the 10 units.

By this contrivance the 10 unit is referred to the single standard.

To determine the value of a coil of 100 units, the three 3 units can be replaced by three 30 units, and the single units by tens.

This, however, is not the most convenient method for the total resistance if the wire of the Fleming bridge in use is only $\frac{1}{20}$ of a unit, thus affording too small a range for the ready comparison of large resistances.

The following has been adopted:—Four coils are arranged as in a Wheatstone's Bridge, one being the 100 units to be tested, two of the others in opposite arms, two known 10 units, and the fourth a known single unit.

These coils are all arranged in the same circular trough of water and their electrodes dip into four mercury cups.

If all the coils are correct no current will traverse the galvanometer. Of course in practice this condition is never realised. Either one of the ten units or the single unit is too great. Let us suppose it is the latter; connect its two electrodes with the two electrodes of a resistance box and take out plugs from this till a balance is secured. Then if the resistance of the ten units be Q and R, that of the single unit S, and the shunt W, the resistance of the shunted arm is $\frac{W\,S}{W + S}$, and that of the 100 units is $\frac{Q\,R\,(W + S)}{W\,S}$.

Now, in practice, if Q, R, S are fairly accurate, W will be a large resistance, and an approximate knowledge of W will suffice. W may thus, for all we require, be taken from a resistance box by a good maker which has stood for some time in the room in which the experiments are conducted, the temperature being taken as that of the room. A box has been ordered from Messrs. Elliott Brothers, to be used for this and similar purposes.

The same firm have also supplied a high resistance galvanometer for the testing.

Of course if one of the ten unit coils is too great, then the shunt W must be put in with it.

In accordance with the resolution of the Committee, a fee of 1*l*. 1*s*. has been charged for testing single units, and of 1*l*. 11*s*. 6*d*. for others.

The only coils the testing of which is regularly undertaken are single units and multiples of single units by some powers of 10.

But though this is so, two standard ohms have been ordered, using for the value of the B. A. unit ·9867 ohms., and when they arrive and have been tested, it will be easy to determine the value of coils which do not

differ much from a real ohm. At present, without these standards—the coils actually used in the recent experiments at the Cavendish Laboratory have a resistance of about ·1, 24, and 168 ohms—the operation is troublesome. The simplest accurate method seems to be to combine in multiple arc the real ohm, and one of the 100 B. A. unit standards, and to compare the combination with a single unit.

Dr. Muirhead also reports the completion of three air condensers as standards of capacity.

The Committee are glad to learn that Lord Rayleigh is continuing his valuable researches at the Cavendish Laboratory with the view of obtaining an absolute unit of current.

They would ask in conclusion that they may be reappointed with the addition of the names of Mr. H. Tomlinson and Professor W. Garnett; and that a further grant of 100*l.* may be made to meet the expense of procuring standards of resistance in terms of the ohm.

Sixteenth Report of the Committee, consisting of Professor EVERETT, Professor Sir WILLIAM THOMSON, Mr. G. J. SYMONS, Sir A. C. RAMSAY, Professor GEIKIE, Mr. J. GLAISHER, Mr. PENGELLY, Professor EDWARD HULL, Professor PRESTWICH, Dr. C. LE NEVE FOSTER, Professor A. S. HERSCHEL, Professor G. A. LEBOUR, Mr. A. B. WYNNE, Mr. GALLOWAY, Mr. JOSEPH DICKINSON, Mr. G. F. DEACON, Mr. E. WETHERED, *and* Mr. A. STRAHAN, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Professor EVERETT (*Secretary*).

OBSERVATIONS have been made in the artesian well at Southampton Common by Mr. T. W. Shore, of the Hartley Institution, assisted by Mr. J. Blount Thomas.

The well was sunk to a depth of 1,317 feet many years ago, and has remained closed for thirty-two years. It has now been re-opened, with the view of being carried deep enough to obtain a supply of water which will rise to the surface. The brick portion of the well is 563 feet deep, with a diameter of 13 feet at the top and 7 feet at the bottom. A boring with a $7\frac{1}{2}$-inch auger was made 754 feet deeper, giving a total depth of 1,317 feet. The water stands at 40 feet below the surface of the ground, and a tube about $7\frac{1}{2}$ inches in diameter extends from the bottom of the brick well to a few inches above the surface of the water. The thermometer (an inverted Negretti maximum) was lowered through this tube into the boring, and, to aid in carrying it past obstructions, it was enclosed in a perforated cylindrical case of zinc, to which was attached an elongated cylindrical weight, pointed at the lower end to enable it to penetrate mud. The result showed that these precautions were necessary, the zinc case and the lower part of the weight being deeply scratched. The obstructions were chiefly met with at a depth of from 600 to 800 feet, in passing through the Upper Chalk.

The thermometer was lowered very gradually, its descent occupying

nearly 15 minutes, and it met with chalk mud at a depth of 1,210 feet from the surface of the ground. Here it was allowed to remain for 30 minutes. It was then hauled up as slowly as it had gone down, and its indication was 69°·7 F.

Observations were next taken in the same manner at two smaller depths, the temperatures recorded being 57° F. at 400 feet and 65°·1 F. at 800 feet.

The thermometer was then lowered again to the same depth as at first, and showed a temperature 2°·2 higher, but the lowering and raising on this occasion were hurried, as it was getting dark, and it is probable that the 2°·2 of excess were owing to mercury which was shaken out of the bulb into the stem during the hauling up.

These observations were made on January 18. After correspondence with the Secretary the thermometer was again lowered to the full depth, and allowed to remain there for a week. It was hauled up on February 1, and read 69°·7—exactly the same as in the first observation.

By way of verifying the explanation above given of the 2°·2 of excess observed on the second occasion, Mr. Shore has tested the effect of shaking the thermometer by hand, and finds that he can, by a few jerks, cause a sufficient quantity of mercury to pass through from the bulb to make this difference.

All these observations were taken before the water had been disturbed by any preparations for continuing the boring, and the temperature 69°·7 at 1,210 feet may be accepted as truly representing the temperature of the ground at this depth.

The mean annual temperature of the air at Southampton, as calculated by Mr. Shore from the daily observations at the Ordnance Survey Office, for the ten years 1872–1881, is 50°·0 F. If we allow, in accordance with general experience, an excess of 1° in surface temperature of the soil, we have an increase of 18°·7 in 1,210 feet, which is at the rate of 1° F. in 65 feet.

Judging from past experience, not much reliance can be placed on the temperatures at intermediate depths, as they are liable to be largely affected by convection. In the present case a comparison of the temperatures at 800 feet and 1,210 feet gives an increase of 1° in 89 feet, and a comparison of those at 400 feet and 1,210 feet gives 1° in 64 feet.

The temperature of the surface of the water on January 18 was 55°. This was only 40 feet below the surface of the ground, and the temperature of the air at the time was 49°. The surface of the ground is 140 feet above sea-level.

The Council of the Mining Institute of Cornwall have undertaken a series of observations on underground temperature in Dolcoath mine. The thermometers (of the usual slow-action pattern) were supplied by our Secretary at the expense of the Mining Institute, and the observations were taken by Captain Josiah Thomas, the manager of the mine. It is the deepest mine in Cornwall, and observations have been taken at six points, at depths ranging from 252 to 2,124 feet.

The deepest of these six observations was taken under very satisfactory conditions, being in clean granite, about 90 feet distant from any draught, and in newly-opened ground, only 24 feet from the end of the working. The temperature observed here—the thermometer having been left for some days in a hole bored for it—was 83° F., and the mean

temperature of the air in the district for the past thirty-five years is given by Dr. Hudson, of Redruth, as 51°·4. Assuming 52°·5 as the mean temperature of the surface of the ground, we have an increase of 30°·5 in 2,124 feet, which is at the rate of 1° F. in 70 feet.

This determination seems to be worthy of all confidence. The other five observations were in places which had been for long periods exposed to the air. The six observations, in order of depth, are given in the following table. The last column shows the rate calculated by comparing the depth in question with an assumed temperature of 52°·5 at the surface.

Station	Depth in feet	Temp. Fahr.	Excess over surface	Feet per degree of increase
I.	252	64	11·5	22
II.	390	65	12·5	31
III.	876	67·8	15·3	57
IV.	1118	65	12 5	89
V.	1884	70	17·5	108
VI.	2124	83	30·5	70

Captain Thomas states that in the level where Station IV. was situated a cold current of air had been passing until quite recently; also that the observation at Station V. is of little value, being made in a narrow portion of rock left between two lodes which had been worked away.

All the obervations were taken in holes bored in the rock, not in the mineral veins. The rock is granite, except for the first 800 feet, which consist of a compact slate-rock called 'killas,' up to within 20 or 30 feet of the surface. There was a large quantity of pyrites in the upper workings, but the lode in these places was worked away seventy or eighty years ago. There is no pyrites in the deep workings, and no heating by chemical action has been noticed. The lode in the deepest part is chiefly composed of chlorite, quartz, and tin ores. All the holes in which observations were taken were dry. Water issues from the rock to the south of the lode at the bottom of the engine shaft (120 feet below the deepest of the six observations) at a temperature of about 90°. The mine has been worked for about 120 years, copper being obtained in the upper and tin in the lower portions.

A second set of observations under the sea have been obtained by Professor Lebour; this time from North Seaton Colliery, a few miles distant from Newcastle. A slow-action thermometer was employed, in the usual manner, and six readings were taken, all showing the same temperature, 61°. The point of observation was half a mile beyond low-water mark, and 660 feet below mean sea-level (Ordnance datum). The depth of water, according to the Admiralty charts, is from 5 to 6 fathoms, and as these charts give the depth of low water of spring tides, the depth at mean tide may be taken as about 40 feet. The point of observation is, therefore, 620 feet below the sea-bottom. Assuming the mean temperature of the sea-bottom to be 48°, we have an increase of 13° in 620 feet, which is at the rate of 1° in 48 feet.

Mr. E. Garside has taken another observation in Ashton Moss Colliery, 90 feet deeper than before. He finds a temperature of 84° at the depth of 2,880 feet, whereas he previously found 85°·3 at the depth of 2,790 feet. The thermometer used was the same, but it was left forty-

eight hours in the hole, besides three hours allowed before insertion; whereas in the previous observation (1881 Report) it was only left six hours in the hole, with ten or fifteen minutes before insertion. Assuming, as before, a surface temperature of 49°, we have an increase of 35° in 2,880 feet, which is at the rate of 1° in 82 feet.

Mr. Garside has also furnished the results of one year's observations of surface temperature at two stations in Ashton-under-Lyne, in the immediate vicinity of the pits in which his observations have been taken. One station is Croft House, in the centre of the town, 345 feet above sea-level; and the other is the District Infirmary, 501 feet above sea-level. In both cases the data furnished are the monthly means, for the year 1882, of daily observations of the temperature of the soil at 4 feet deep and 1 foot deep; also of the maximum and minimum temperatures of the air. The annual mean for the thermometer 4 feet deep is 47°·5 at Croft House, and 45°·9 at the Infirmary. For the thermometer 1 foot deep the numbers are 46°·2 and 45°·6; and for the half-sum of maximum and minimum 48°·4 and 46°·6. Unless the year 1882 was exceptionally cold, our assumption of a surface temperature of 49° would therefore appear to be in excess of the truth; but further time must be allowed to settle this question.

The Secretary has been consulted by the Trustees of the Lick Observatory, about to be erected on a mountain in California, as to the advisability of taking observations of underground temperature there, and the best method to be followed. He has recommended observations at various points for comparing the temperature at 3 feet deep with the temperature of the air.

One inverted Negretti-maximum and two slow-action thermometers have been entrusted to Mr. T. W. Edgeworth David, Assistant Field Geologist to the Mining Department in New South Wales; and two slow-action thermometers have been supplied to the Engineering Department of the South-Eastern Railway, for observations in the Channel Tunnel.

Since the publication of the 'Summary,' which accompanied last year's Report, the Secretary has received from Dr. Stapff a communication which renders an important modification necessary in the results for the St. Gothard and Mont Cenis Tunnels. In the 'Summary' a conjectural correction was applied for the convexity of the mountain surfaces. Dr. Stapff's calculations lead to the conclusion that a much larger allowance must be made under this head. He deduces 1° F. in 85 feet as the actual average rate of increase from the surface overhead to the tunnel; and he calculates that at a depth below the tunnel sufficient to make the isothermal surfaces sensibly plane, the increase is 1° F. in 57·8 feet. His method of calculation is very elaborate and laborious. He first divides the whole length of the tunnel into sections, and, assuming that the isotherms are parabolas, investigates the parabolic isotherm for each section. Then, by combining these, he deduces a general law for the whole length, and infers that at the depth at which the isotherms are flattened out into straight lines the rate of increase is 1° F. for 57·8 feet of descent.

As a check upon this very elaborate method, the secretary requested Dr. Stapff to furnish him with the actual observations both above ground and in the tunnel, for that portion which passes under the plain of Andermatt. This Dr. Stapff has kindly done, and these observations

strongly support Dr. Stapff's deduction as against the deduction given in the 'Summary;' the actual increase from the surface to the tunnel in this part being at a much more rapid rate than 1° F. in 57·8 feet—namely, at 1° F. in 38 feet.

As a guide for future estimates, it may be noted that the correcting factor for reducing 85 feet to 57·8 feet is almost exactly $\frac{2}{3}$; but if we compare the result merely with the observed increase beneath the crest of the mountain, which was 1° F. in 100 feet, the correcting factor to be applied to 100 feet is ·58.

If we assume 1° in 57·8 feet as the rate for the St. Gothard Tunnel, and also for the Mont Cenis Tunnel, instead of the rates assumed in the 'Summary,' the effect upon the general mean for all places will be to make it 1° F. in 60 feet, instead of 1° F. in 64 feet.

[Dr. Stapff's paper has been printed *in extenso*, with the Andermatt observations as an Appendix, in the Transactions of the North of England Mining Institute for 1883.]

Report of the Committee consisting of Captain ABNEY, Professor STOKES, *and* Professor SCHUSTER (*Secretary*), *appointed for the purpose of determining the best Experimental Methods that can be used in observing Total Solar Eclipses.*

THE Committee has considered it advisable to adjourn its discussion until the results of the last total solar eclipse should be known. As the eclipse expedition which went out to observe that eclipse has returned only a short time ago, the Committee desires its reappointment without grant of money.

Report of a Committee, consisting of Professors G. H. DARWIN *and* J. C. ADAMS, *for the Harmonic Analysis of Tidal Observations. Drawn up by* G. H. DARWIN.

Preface.—Account of Operations.

A COMMITTEE appointed for the examination of the question of the Harmonic Analysis of Tidal Observations practically finds itself engaged in the question of the reduction of Indian Tidal Observations; since it is only in that country that any extensive system of observation with systematic publication of results [1] exists. This at least has proved to be the case with our committee. On communication with General Strachey, it was found that the India Office was anxious to obtain advice as to the reduction of observations and publication of results, and that Major A. W. Baird, R.E., the officer in charge at Poona of the Tidal Department of the Survey of India, felt the desirability of instruc-

[1] *Indian Tide Tables*, published by authority of the Secretary of State.

tion with regard to several points. More recently, in a resolution dated, Simla, June 1, 1883 :—'The Government of India notices with pleasure that the tidal observations, in addition to their practical value for the requirements of navigation, are now furnishing information which is found to be of much scientific value.' The resolution then refers to a paper on the rigidity of the earth, which was read at the last meeting of the Association.

During 1882 Major Baird was in Europe, and Sir William Thomson was kind enough to permit me to arrange a meeting with Major Baird, in December, at his house in Glasgow, in order to discuss the subject, in continuation of our previous correspondence.

We then arrived at a general idea of the course of future procedure, and also came to some agreement as to the changes of notation which it was desirable to adopt. Subsequently, I proceeded to draw up a considerable part of this Report, had it printed, and submitted it to Major Baird. I was not at that time aware of the extent to which Mr. Roberts, of the *Nautical Almanac* office, co-operated in England in the tidal operations, nor did I know that he was not unfrequently taking the advice of Professor Adams. It was not until Major Baird had read what I had written, and expressed his approval of the methods suggested, that these facts came to my knowledge; but it must be admitted that it was through my own carelessness that this was so. I then found that Professor Adams decidedly disapproved of the notation adopted, and would have preferred to throw over the notation of the old Reports and take a new departure. The notation of the old Reports seems to me also to be unsatisfactory, but, seeing that Major Baird and his staff were already familiar with that notation, I considered that an entire change would be impolitic, and that it was better to allow the greater part of the existing notation to stand, but to introduce modifications. The fact that Major Baird, who was actually to work the method, approved of what had been written, and had already mastered it, went far to prejudge the question, and Professor Adams agreed, after discussion, that it would on the whole be best to allow the work to go on in the lines in which it had been started.

It has seemed proper to give this account of our operations in order that Professor Adams may be relieved from responsibility for the analytical methods and notation here adopted. I may state, however, that although the Report is drawn up in a form probably differing widely from that which it would have had if Professor Adams had been the author, yet he agrees with the correctness of the methods pursued. I have been in constant communication with him for the past eight months, and have received many valuable criticisms and suggestions.

Mr. Roberts has been supervising the printing of a new edition of the computation forms; they have undergone some modification in accordance with this Report. He has also computed certain new coefficients [Schedule Q] which are required in the reductions.

Major Baird returned to India in the spring of 1883, and, as I learn, will shortly begin revising all the published results, so as to bring them to one uniform system—namely, that here recommended. We are now supplying Mr. Neison at Natal with a copy of this Report, and a few copies of the computation forms will be sent to him for the purpose of reducing the South African Tidal Observations.

The general scope of this paper is to form a manual for the reduction of tidal observations by the Harmonic Analysis inaugurated by Sir

William Thomson, and carried out by the previous Committee of the British Association.[1]

In the present Report the method of mathematical treatment differs considerably from that of Sir William Thomson.[2] In particular, he has followed, and extended to the diurnal tides, Laplace's method of referring each tide to the motion of an *astre fictif* in the heavens, and he considers that these fictitious satellites are helpful in forming a clear conception of the equilibrium theory of tides. As, however, I have found the fiction rather a hindrance than otherwise, I have ventured to depart from this method, and have connected each tide with an 'argument,' or an angle increasing uniformly with the time and giving by its hourly increase the 'speed' of the tide. In the method of the *astres fictifs*, the speed is the difference between the earth's angular velocity of rotation and the motion of the fictitious satellite amongst the stars. It is a consequence of the difference in the mode of treatment, and of the fact that the elliptic tides are here developed to a higher degree of approximation, that none of the present Report is quoted from the previous ones.

The Report of 1876 was not intended to be a final production, and it did not contain any complete explanation of a considerable portion of the numerical operations of the Harmonic Analysis.

The present Report is intended to systematise the exposition of the theory of the harmonic analysis, to complete the methods of reduction, and to explain the whole process.

A careful survey of the methods hitherto in use has brought to light a good many minor points in which improvements may be introduced, but it has seemed desirable not to disturb the system, which is in working order, more than can be helped. It has also appeared that the published results have not been arranged in a form which lends itself to a satisfactory examination of the whole method. This defect will, we hope, now be remedied; and, as above stated, Major Baird will revise the Indian results.

The first section refers to the notation, and contains a schedule of nomenclature by initials of the several tides under examination. The schedule is not, strictly speaking, in its proper position at the beginning, because it involves the results of subsequent analysis, but the advantage gained by having this list in a position of easy reference seems to outweigh the want of logic.

The forms for computation are privately printed for the India Office, and are therefore inaccessible to the public.[3] The type has been broken up, and very few copies remain, but we shall be able to send copies to the Libraries of the following Societies, viz.: Royal Society, London; the Academies of Science of Paris, Berlin, and Vienna, and the Coast Survey of the United States at Washington.

G. H. DARWIN.

[1] See especially the Reports for 1872 and 1876.

[2] The present method of development is that pursued in a paper in the *Phil. Trans. R.S*, Part II. 1880, p. 713.

[3] It may be useful to mention that I hope to publish an edition of the forms, reproducing them by photozincography. The price will be just such as to cover the expense.

§ 1. *The Notation adopted in the Tidal Reports.*

In considering the notation to be adopted, much weight should be given to the fact that a large mass of analysis and computation already exists in a certain form. We have not thus got a *tabula rasa* to work on, but had better accept a good deal that has grown up by a process of accretion. It is certainly unfortunate that a dual system should have been adopted, in which one set of letters are derived from the Greek and another from the English.

The letters γ, σ, η, ϖ are appropriated respectively to the earth's angular velocity of rotation, to the mean motions of the moon, sun, and lunar perigee. They form the initial letters of the words γῆ, σελήνη, ἥλιος, and perigee. There is also ω, derived from the obliquity of the ecliptic. In another category we have M, S, E, for the masses of the moon, sun, and earth. It is unfortunate that the letter S should thus be connected with the moon in σ; but it has not been thought advisable to change the notation in this matter. In this Report the already existing notation is adhered to, as far as might be without inconvenience; but it must be admitted that the notation is by no means satisfactory.

It is a matter of great practical utility to have a symbol for indicating special tides. In the endeavour to meet this want initial letters were assigned in the former Reports to each kind of tide; but, except in the case of M and S, for the principal 'moon' and 'sun' tides, the initials had no connection with the tide. Although a new system of initials might be devised which would have a direct connection with the tides to which they refer, yet it has appeared best to adhere to the old initials and to introduce certain new initials for the tides of long period and for some tides now considered for the first time.

In the old notation the L tide was simply the tide of speed $2\gamma-\sigma-\varpi$. The values of this tide have probably been perturbed by another tide of speed $2\gamma-\sigma+\varpi$, and this tide is supposed also to be included in L.

Where it is necessary to refer to any other tides than those contained in this schedule, it will be best to use the scientific nomenclature simply by speed. For example, there may be a compound tide $3\gamma-2\eta$; and though this tide might be called SK, since $3\gamma-2\eta=2(\gamma-\eta)+\gamma$, yet reference to such a tide will be so infrequent as not to make the short notation desirable.

Both the old and the new initials are given in the following schedule.

[A.] *Schedule of Notation.*

Initials	Speed	Name of Tide
M_1	$\gamma-\sigma-\varpi$, and $\gamma-\sigma+\varpi$	Principal lunar series
M_2	$2(\gamma-\sigma)$	
M_3	$3(\gamma-\sigma)$	
&c.	&c.	
K_2	2γ	Luni-solar semi-diurnal
N	$2\gamma-3\sigma+\varpi$	Larger lunar elliptic
L	$2\gamma-\sigma-\varpi$ and $2\gamma-\sigma+\varpi$	Smaller lunar elliptic
	$2\gamma+\sigma-\varpi$	

Initials	Speed	Name of Tide
2N	$2\gamma-4\sigma+2\varpi$	Lunar elliptic, second order
ν	$2\gamma-3\sigma-\varpi+2\eta$	Larger lunar evectional
λ	$2\gamma-\sigma+\varpi-2\eta$	Smaller lunar evectional
O	$\gamma-2\sigma$	Lunar diurnal
OO	$\gamma+2\sigma$	
K_1	γ	Luni-solar diurnal
Q	$\gamma-3\sigma+\varpi$	Larger lunar elliptic diurnal
	$\gamma-\sigma-\varpi$ included in M_1	Smaller lunar elliptic diurnal
J	$\gamma+\sigma-\varpi$	
	$\gamma-4\sigma+2\varpi$	Lunar elliptic diurnal, second order
	$\gamma-3\sigma-\varpi+2\eta$	Larger lunar evectional diurnal
S_1 S_2 S_3 &c.	$\gamma-\eta$ $2(\gamma-\eta)$ $3(\gamma-\eta)$ &c.	Principal solar series
T	$2\gamma-3\eta$	Larger solar elliptic
R	$2\gamma-\eta$	Smaller solar elliptic
P	$\gamma-2\eta$	Solar diurnal
Mm	$\sigma-\varpi$	Lunar monthly
Mf	2σ	Lunar fortnightly
Sa	η	Solar annual
Ssa	2η	Solar semi-annual
MSf	$2(\sigma-\eta)$	Luni-solar synodic fortnightly
MS	$4\gamma-2\sigma-2\eta$	Compound tides
μ or 2MS	$2\gamma-4\sigma+2\eta$	Compound tides
2SM	$2\gamma+2\sigma-4\eta$	Compound tides
MK	$3\gamma-2\sigma$	Compound tides
2MK	$3\gamma-4\sigma$	Compound tides
MN	$4\gamma-5\sigma+\varpi$	Compound tides

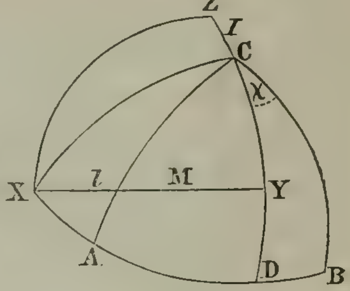
§ 2. *Development of the Equilibrium Theory of Tides with reference to Tidal Observations.*

The first step is the formation of the tide-generating potential of the moon; that for the sun may then be written down by symmetry.

For this purpose we require to find certain spherical harmonic functions of the moon's coordinates, with reference to axes fixed in the earth.

Let A, B, C (Fig. 1) be such axes, C being the north pole and AB the equator.

FIG. 1.



Let X, Y, Z be a second set of axes, XY being the plane of the moon's orbit.

Let M be the projection of the moon in her orbit.

Let I=ZC, the obliquity of the lunar orbit to the equator.

Let χ=AX=BCY.

Let l=MX, the moon's longitude in her orbit, measured from X.

Let

$$\left.\begin{aligned} M_1&=\cos \mathrm{MA} \\ M_2&=\cos \mathrm{MB} \\ M_3&=\cos \mathrm{MC} \end{aligned}\right\} \begin{array}{c}\text{the moon's direction-cosines} \\ \text{with reference to ABC.}\end{array} \quad . \quad . \quad . \quad (1)$$

Then

$$\left.\begin{aligned} M_1&=\cos l \cos \chi+\sin l \sin \chi \cos I \\ M_2&=-\cos l \sin \chi+\sin l \cos \chi \cos I \\ M_3&=\sin l \sin I \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

We may observe that M_2 is derivable from M_1 by putting $\chi+\frac{1}{2}\pi$ in place of χ.

Now for brevity let

$$p=\cos \tfrac{1}{2} I, \quad q=\sin \tfrac{1}{2} I \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Then (2) may be written

$$\left.\begin{aligned} M_1&=p^2 \cos (\chi-l)+q^2 \cos (\chi+l) \\ M_2&=-p^2 \sin (\chi-l)-q^2 \sin (\chi+l) \\ M_3&=2\, pq \sin l. \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Whence

$$\left.\begin{aligned} M_1{}^2-M_2{}^2&=p^4 \cos 2(\chi-l)+2p^2q^2 \cos 2\chi+q^4 \cos 2(\chi+l) \\ -2M_1M_2&=\text{the same with sines in place of cosines.} \\ M_2M_3&=-p^3q \cos (\chi-2l)+pq(p^2-q^2)\cos \chi+pq^3 \cos (\chi+2l) \\ M_1M_3&=\text{the same with sines in place of cosines.} \\ \tfrac{1}{3}-M_3{}^2&=\tfrac{1}{3}(p^4-4p^2q^2+q^4)+2p^2q^2 \cos 2l \end{aligned}\right\} (5)$$

These are the required spherical harmonic functions of M_1, M_2, M_3.

Let M denote the projection of the moon on the celestial sphere concentric with the earth, and P that of any other point.

Let r, ρ be the radius-vectors of the moon and of P respectively, and let ξ, η, ζ be the direction-cosines of P, with reference to the axes A, B, C.

Then $\rho\xi, \rho\eta, \rho\zeta$ are the coordinates of P, and rM_1, rM_2, rM_3 those of M.

If M be the moon's mass, and μ the attraction between unit masses at unit distance apart, then by the usual theory the tide-generating potential V, due to the moon, of the second order of harmonics, at the point P, is given by

$$V = \tfrac{3}{2}\frac{\mu M}{r^3}\rho^2(\cos^2 \mathrm{PM} - \tfrac{1}{3}) \quad . \quad . \quad . \quad . \quad (6)$$

But since $\cos \mathrm{PM} = \xi M_1 + \eta M_2 + \zeta M_3$,

$$\cos^2 \mathrm{PM} - \tfrac{1}{3} = 2\xi\eta M_1M_2 + 2\,\frac{\xi^2-\eta^2}{2}\,\frac{M_1{}^2 - M_2{}^2}{2} + 2\eta\zeta M_2M_3 + 2\xi\zeta M_1M_3$$
$$+\tfrac{3}{2}\,\frac{\xi^2+\eta^2-2\zeta^2}{3}\,\frac{M_1{}^2+M_2{}^2-2M_3{}^2}{3} \quad . \quad . \quad . \quad (7)$$

Now let c be the moon's mean distance, e the eccentricity of the moon's orbit, and let

$$\tau = \tfrac{3}{2}\frac{\mu M}{c^3} \quad . \quad . \quad . \quad . \quad (8)$$

Then putting

$$X = \left[\frac{c\,(1-e^2)}{r}\right]^{\frac{3}{2}} M_1, \qquad Y = \left[\frac{c\,(1-e^2)}{r}\right]^{\frac{3}{2}} M_2, \qquad Z = \left[\frac{c\,(1-e^2)}{r}\right]^{\frac{3}{2}} M_3 \quad (9)$$

We have

$$V \div \frac{\tau}{(1-e^2)^3}\rho^2 = 2\xi\eta\,XY + 2\,\frac{\xi^2-\eta^2}{2}\,\frac{X^2-Y^2}{2} + 2\eta\zeta\,YZ + 2\xi\zeta\,XZ$$
$$+\tfrac{3}{2}\,\frac{\xi^2+\eta^2-2\zeta^2}{3}\,\frac{X^2+Y^2-2Z^2}{3} \quad . \quad . \quad . \quad (10)$$

A simple tide may be defined as a spherical harmonic deformation of the waters of the ocean which executes a simple harmonic motion in time. Corresponding to this definition the expression for each term of the tide-generating potential should consist of a solid spherical harmonic, multiplied by a simple time-harmonic.

In (10) $\rho^2\xi\eta$, $\rho^2(\xi^2-\eta^2)$, &c., are solid spherical harmonics, and in order to complete the expression for V it is necessary to develop the five functions of X, Y, Z in a series of simple time-harmonics.

It will be now convenient to introduce certain auxiliary functions, namely

$$\left.\begin{array}{l} \Phi\,(a) = \left[\dfrac{c\,(1-e^2)}{r}\right]^3 \cos\,(2l+a), \\ \Psi\,(a) = \left[\dfrac{c\,(1-e^2)}{r}\right]^3 \cos a, \qquad \mathrm{R} = \left[\dfrac{c\,(1-e^2)}{r}\right]^3 \end{array}\right\} \quad . \quad (11)$$

Then from (5) and (9) we have

$$\left.\begin{array}{rl} X^2 - Y^2 = & p^4\Phi\,(-2\chi) + 2p^2q^2\Psi\,(2\chi) + q^4\Phi\,(2\chi) \\ 2XY = & \text{the same with } \chi + \tfrac{1}{4}\pi \text{ for } \chi. \\ YZ = & -p^3q\Phi\,(-\chi) + pq\,(p^2-q^2)\,\Psi\,(\chi) + pq^3\Phi\,(\chi) \\ XZ = & \text{the same with } \chi - \tfrac{1}{2}\pi \text{ for } \chi. \\ \tfrac{1}{3}(X^2+Y^2-2Z^2) = & \tfrac{1}{3}(p^4 - 4p^2q^2 + q^4)\mathrm{R} + 2p^2q^2\Phi\,(0) \end{array}\right\} \quad . \quad (12)$$

Thus when the functions Φ, Ψ, R are developed as a series of time-harmonics, the further development of the X-Y-Z functions consists in substitution in (12).

It will now be supposed that the moon moves in an elliptic orbit, undisturbed by the sun. The tides which arise from the lunar inequalities of the Evection and Variation will be the subject of separate treatment below.

The descending node of the equator on the lunar orbit will henceforth be called 'the Intersection.'

Let $\sigma_{,}$ be the moon's mean longitude measured in her orbit from the intersection, and $\varpi_{,}$ the longitude of the perigee measured in the same way. It has been already defined that l is the moon's longitude in her orbit measured from the intersection.

The equation of the ellipse described by the moon is

$$\frac{c\,(1-e^2)}{r}=1+e\cos(l-\varpi_{,})\quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Hence

$$\left.\begin{aligned}
\mathrm{R}&=1+\tfrac{3}{2}e^2+3e\cos(l-\varpi_{,})+\tfrac{3}{2}e^2\cos 2(l-\varpi_{,})+\ .\ .\ .\\
\Phi(\alpha)&=\mathrm{R}\cos(2l+\alpha)\\
&=(1+\tfrac{3}{2}e^2)\cos(2l+\alpha)+\tfrac{3}{2}e[\cos(3l+\alpha-\varpi_{,})+\cos(l+\alpha+\varpi_{,})]\\
&\qquad+\tfrac{3}{4}e^2[\cos(4l+\alpha-2\varpi_{,})+\cos(\alpha+2\varpi_{,})]+\ .\ .\ .\\
\Psi(\alpha)&=\mathrm{R}\cos\alpha
\end{aligned}\right\}\quad(14)$$

By the theory of elliptic motion

$$l=\sigma_{,}+2e\sin(\sigma_{,}-\varpi_{,})+\tfrac{5}{4}e^2\sin 2(\sigma_{,}-\varpi_{,})+\ .\ .\ .\quad .\ .\quad (15)$$

In order to expand Φ, Ψ, R in terms of $\sigma_{,}$ (which increases uniformly with the time), we require $\cos(2l+\alpha)$ developed as far as e^2; $\cos(3l+\alpha-\varpi)$, and $\cos(l+\alpha+\varpi)$, as far as e; and only the first term of $\cos(4l+\alpha-2\varpi_{,})$.

Substituting for l its value (15) in terms of $\sigma_{,}$, it is easy to show that

$$\begin{aligned}
\cos(2l+\alpha)&=(1-4e^2)\cos(2\sigma_{,}+\alpha)-2e\cos(\sigma_{,}+\alpha+\varpi_{,})+2e\cos(3\sigma_{,}+\alpha-\varpi_{,})\\
&\qquad+\tfrac{3}{4}e^2\cos(\alpha+2\varpi_{,})+\tfrac{13}{4}e^2\cos(4\sigma_{,}+\alpha-2\varpi_{,})+\ .\ .\ .\ .\\
\cos(3l+\alpha-\varpi_{,})&=\cos(3\sigma_{,}+\alpha-\varpi_{,})\\
&\qquad-3e\cos(2\sigma_{,}+\alpha)+3e\cos(4\sigma_{,}+\alpha-2\varpi_{,})+\ .\ .\ .\ .\\
\cos(l+\alpha+\varpi_{,})&=\cos(\sigma_{,}+\alpha+\varpi_{,})+e\cos(2\sigma_{,}+\alpha)-e\cos(\alpha+2\varpi_{,})+\ .\ .\ .\\
\cos(4l+\alpha-2\varpi_{,})&=\cos(4\sigma_{,}+\alpha-2\varpi_{,})+\ .\ .\ .\ .
\end{aligned}$$

Substituting these values in (14) we find,

$$\left.\begin{aligned}
\Phi(\alpha)&=(1-\tfrac{11}{2}e^2)\cos(2\sigma_{,}+\alpha)-\tfrac{1}{2}e\cos(\sigma_{,}+\alpha+\varpi_{,})\\
&\qquad+\tfrac{7}{2}e\cos(3\sigma_{,}+\alpha-\varpi_{,})+\tfrac{17}{2}e^2\cos(4\sigma_{,}+\alpha-2\varpi_{,})+\ .\ .\ .\ .\\
\mathrm{R}&=(1-\tfrac{3}{2}e^2)+3e\cos(\sigma_{,}-\varpi_{,})+\tfrac{9}{2}e^2\cos 2(\sigma_{,}-\varpi_{,})+\ .\ .\ .\ .\\
\Psi(\alpha)&=(1-\tfrac{3}{2}e^2)\cos\alpha+\tfrac{3}{2}e[\cos(\sigma_{,}+\alpha-\varpi_{,})+\cos(\sigma_{,}-\alpha-\varpi_{,})]\\
&\qquad+\tfrac{9}{4}e^2[\cos(2\sigma_{,}+\alpha-2\varpi_{,})+\cos(2\sigma_{,}-\alpha-2\varpi_{,})]+\ .\ .\ .
\end{aligned}\right\}\quad(16)$$

Now substituting from (16) in (12), giving to α its appropriate value, we have

$$\left.\begin{aligned}
X^2-Y^2=(1-\tfrac{11}{2}e^2)[p^4\cos 2(\chi-\sigma_,)+q^4\cos 2(\chi+\sigma_,)]&\\
+(1-\tfrac{3}{2}e^2)\,2p^2q^2\cos 2\chi&\\
+\tfrac{7}{2}e\,[p^4\cos(2\chi-3\sigma_,+\varpi_,)+q^4\cos(2\chi+3\sigma_,-\varpi_,)]&\\
-\tfrac{1}{2}e\,[p^4\cos(2\chi-\sigma_,-\varpi_,)+q^4\cos(2\chi+\sigma_,+\varpi_,)]&\\
+\tfrac{3}{2}e\,2p^2q^2\,[\cos(2\chi+\sigma_,-\varpi_,)+\cos(2\chi-\sigma_,+\varpi_,)]&\\
+\tfrac{17}{2}e^2[p^4\cos(2\chi-4\sigma_,+2\varpi_,)+q^4\cos(2\chi+4\sigma_,-2\varpi_,)]&\\
+\tfrac{9}{4}e^2 2p^2q^2[\cos(2\chi+2\sigma_,-2\varpi_,)+\cos(2\chi-2\sigma_,+2\varpi_,)]&
\end{aligned}\right\}\quad(17)$$

Clearly $-2XY$ is the same as (17) with sines in place of cosines. Also since YZ is the same as X^2-Y^2 when χ replaces 2χ, $-p^3q$ replaces p^4, $pq(p^2-q^2)$ replaces $2p^2q^2$, and pq^3 replaces q^4, and since XZ is the same as YZ with sines in place of cosines, we have from (17)

$$\left.\begin{aligned}
XZ=-(1-\tfrac{11}{2}e^2)[p^3q\sin(\chi-2\sigma_,)-pq^3\sin(\chi+2\sigma_,)]&\\
+(1-\tfrac{3}{2}e^2)\,pq\,(p^2-q^2)\sin\chi&\\
-\tfrac{7}{2}e\,[p^3q\sin(\chi-3\sigma_,+\varpi_,)-pq^3\sin(\chi+3\sigma_,-\varpi_,)]&\\
+\tfrac{1}{2}e\,[p^3q\sin(\chi-\sigma_,-\varpi_,)-pq^3\sin(\chi+\sigma_,+\varpi_,)]&\\
+\tfrac{3}{2}epq\,(p^2-q^2)[\sin(\chi+\sigma_,-\varpi_,)+\sin(\chi-\sigma_,+\varpi_,)]&\\
-\tfrac{17}{2}e^2\,[p^3q\sin(\chi-4\sigma_,+2\varpi_,)-pq^3\sin(\chi+4\sigma_,-2\varpi_,)]&\\
+\tfrac{9}{4}e^2\,pq(p^2-q^2)\,[\sin(\chi+2\sigma_,-2\varpi_,)+\sin(\chi-2\sigma_,+2\varpi_,)]&
\end{aligned}\right\}\quad(18)$$

Lastly,

$$\begin{aligned}
\tfrac{1}{3}(X^2+Y^2-2Z^2)=\tfrac{1}{3}(p^4-4p^2q^2+q^4)[(1-\tfrac{3}{2}e^2)+3e\cos(\sigma_,-\varpi_,)&\\
+\tfrac{9}{2}e^2\cos 2(\sigma_,-\varpi_,)]&\\
+2p^2q^2[(1-\tfrac{11}{2}e^2)\cos 2\sigma_,+\tfrac{7}{2}e\cos(3\sigma_,-\varpi_,)-\tfrac{1}{2}e\cos(\sigma_,+\varpi_,)&\\
+\tfrac{17}{2}e^2\cos(4\sigma_,-2\varpi_,)]&\quad .\quad(19)
\end{aligned}$$

Hitherto no approximation has been admitted with regard to I, the obliquity of the lunar orbit to the equator.

The obliquity of the ecliptic is 23° 27′·3, and I oscillates between 5° 8′·8 greater and 5° 8′·8 less than that value. The value of q or $\sin\frac{1}{2}I$, when I is 23° 27′·3, is ·203, and its square is ·041, and its cube ·0084. The eccentricity of the lunar orbit $e=$·0549; hence q^2 is a little smaller than e.

The preceding developments have been carried as far as e^2, principally on account of the terms involving $\frac{17}{2}e^2$, which, as e is about $\frac{1}{18}$, have nearly the same magnitude as if the coefficient had been $\frac{1}{2}e$.

It is proposed, then, to regard q^2 and q^3 as of the same order as e, and to drop all terms of the order e^2, except in the case where the numerical factor is large. This rule will be neglected with regard to one term for a special reason, which appears below; and for another, because the numerical coefficient is just sufficiently large to make it worth retaining.

Adopting this approximation, we may write (17), (18), (19), thus,—

$$
\left.\begin{aligned}
X^2-Y^2 &= (1-\tfrac{11}{2}e^2)\,p^4\cos 2(\chi-\sigma_{,})+(1-\tfrac{3}{2}e^2)\,2p^2q^2\cos 2\chi \\
&\quad +\tfrac{7}{2}ep^4\cos(2\chi-3\sigma_{,}+\varpi_{,}) \\
&\quad -\tfrac{1}{2}ep^2\left[p^2\cos(2\chi-\sigma_{,}-\varpi_{,})-6q^2\cos(2\chi-\sigma_{,}+\varpi_{,})\right] \\
&\quad +\tfrac{17}{2}e^2p^4\cos(2\chi-4\sigma_{,}+2\varpi_{,}) \\
XZ &= -(1-\tfrac{11}{2}e^2)\left[p^3q\sin(\chi-2\sigma_{,})-pq^3\sin(\chi+2\sigma_{,})\right] \\
&\quad +(1-\tfrac{3}{2}e^2)\,pq\,(p^2-q^2)\sin\chi-\tfrac{7}{2}ep^3q\sin(\chi-3\sigma_{,}+\varpi_{,}) \\
&\quad +\tfrac{1}{2}epq\left[p^2\sin(\chi-\sigma_{,}-\varpi_{,})+3\,(p^2-q^2)\sin(\chi-\sigma_{,}+\varpi_{,})\right] \\
&\quad +\tfrac{3}{2}epq\,(p^2-q^2)\sin(\chi+\sigma_{,}-\varpi_{,})-\tfrac{17}{2}e^2p^3q\sin(\chi-4\sigma_{,}+2\varpi_{,}) \\
\tfrac{1}{3}(X^2+Y^2-2Z^2) &= \tfrac{1}{3}(p^4-4p^2q^2+q^4)\left[(1-\tfrac{3}{2}e^2)+3e\cos(\sigma_{,}-\varpi_{,})\right] \\
&\quad +2p^2q^2\left[(1-\tfrac{11}{2}e^2)\cos 2\sigma_{,}+\tfrac{7}{2}e\cos(3\sigma_{,}-\varpi_{,})\right]
\end{aligned}\right\}\quad (20)
$$

The terms which have been retained in violation of the rule of approximation are that in X^2-Y^2 with argument $2\chi-\sigma_{,}+\varpi_{,}$, and that in $\frac{1}{3}(X^2+Y^2-2Z^2)$ with argument $3\sigma_{,}-\varpi_{,}$.

The only other term which could have any importance is

$$\tfrac{3}{2}e\,2p^2q^2\cos(2\chi+\sigma_{,}-\varpi_{,})\text{ in }X^2-Y^2.$$

Before proceeding to consider the tides due to lunar inequalities it will be well to consider two pairs of terms in the expressions (20).

First, in X^2-Y^2 we have the terms

$$-\tfrac{1}{2}ep^2\left[p^2\cos(2\chi-\sigma_{,}-\varpi_{,})-6q^2\cos(2\chi-\sigma_{,}+\varpi_{,})\right]$$

The expression within [ ] may be written

$$(p^2-6q^2\cos 2\varpi_{,})\cos(2\chi-\sigma_{,}-\varpi_{,})+6q^2\sin 2\varpi_{,}\sin(2\chi-\sigma_{,}-\varpi_{,})$$

$$=p\sqrt{p^2-12q^2\cos 2\varpi_{,}}\cos(2\chi-\sigma_{,}-\varpi_{,}-R)\text{ approximately;}$$

where

$$\tan R=\frac{\sin 2\varpi_{,}}{\frac{1}{6}\cot^2\frac{1}{2}I-\cos 2\varpi_{,}}\quad\ldots\ldots\quad(20^{\text{i}})$$

Thus this pair of terms may be written

$$-\tfrac{1}{2}ep^4\sqrt{\{1-12\tan^2\tfrac{1}{2}I\cos 2\varpi_{,}\}}\cos(2\chi-\sigma_{,}-\varpi_{,}-R)\quad.\quad(20^{\text{ii}})$$

Secondly, in XZ we have the terms

$$+\tfrac{1}{2}epq\left[p^2\sin(\chi-\sigma_{,}-\varpi_{,})+3\,(p^2-q^2)\sin(\chi-\sigma_{,}+\varpi_{,})\right]$$

This is approximately equal to

$$+\tfrac{1}{2}ep^3q\left[4\cos\varpi_{,}\sin(\chi-\sigma_{,})+2\sin\varpi_{,}\cos(\chi-\sigma_{,})\right]$$

$$=ep^3q\sqrt{\{\tfrac{5}{2}+\tfrac{3}{2}\cos 2\varpi_{,}\}}\sin(\chi-\sigma_{,}+Q)\quad.\quad.\quad(20^{\text{iii}})$$

where

$$\tan Q=\tfrac{1}{2}\tan\varpi_{,}\quad\ldots\ldots\ldots\quad(20^{\text{iv}})$$

The object of the transformations (20^{ii}), (20^{iv}), which may seem theoretically undesirable, is as follows:—

The numerical harmonic analysis of the tides is made to extend over

one year, and this period is not long enough to distinguish completely a tide whose argument is $2\chi-\sigma_{,}-\varpi_{,}$, from one whose argument is $2\chi-\sigma_{,}+\varpi_{,}$, nor one whose argument is $\chi-\sigma_{,}-\varpi_{,}$, from one whose argument is $\chi-\sigma_{,}+\varpi_{,}$. In fact, the tide with argument $2\chi-\sigma_{,}+\varpi_{,}$ (for which no analysis has been as yet carried out) will only produce an irregularity in that of argument $2\chi-\sigma_{,}-\varpi_{,}$, called the smaller elliptic semidiurnal tide; such irregularity has in fact been noted, but no explanation has previously been given of it.

Again, the pair of terms with arguments $\chi-\sigma_{,}\pm\varpi_{,}$ will appear in the harmonic analysis with the single argument $\chi-\sigma_{,}$, and the resulting numbers will necessarily appear very irregular, unless compared with the theoretical expression (20^{iii}).

We will now consider the terms introduced by the two principal lunar inequalities due to the disturbing action of the sun.

The Evection.

Let θ be the moon's longitude in the ecliptic.

s the moon's mean longitude.

p the mean longitude of the perigee.[1]

h the sun's mean longitude.

m the ratio of the sun's to the moon's mean motion.

Then that inequality in longitude and radius vector is represented by

$$\theta=s+\tfrac{15}{4}me\sin(s-2h+p) \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

$$\frac{c(1-e^2)}{r}=1+\tfrac{15}{8}me\cos(s-2h+p) \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

If we neglect the distinction between longitudes in the orbit and in the ecliptic [which is in effect neglecting a term with coefficient $\sin^2(\frac{1}{2}\times 5°\ 9')$], we have from (21),

$$l=\sigma_{,}+\tfrac{15}{4}me\cos(s-2h+p);$$

whence

$$\cos(2l+\alpha)=\cos(2\sigma_{,}+\alpha)+\tfrac{15}{4}me\,[\cos(2\sigma_{,}+s-2h+p+\alpha)$$
$$-\cos(2\sigma_{,}-s+2h-p+\alpha)]$$

And from (22) and the definitions of R, Ψ, Φ in (11),

$$\mathrm{R}=\left[\frac{c(1-e^2)}{r}\right]^3=1+\tfrac{45}{8}me\cos(s-2h+p) \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

$$\Psi(\alpha)=\cos\alpha+\tfrac{45}{16}me\,[\cos(s-2h+p+\alpha)+\cos(s-2h+p-\alpha)] \quad . \quad . \quad (24)$$

$$\Phi(\alpha)=\cos(2\sigma_{,}+\alpha)+\tfrac{105}{16}me\cos(2\sigma_{,}+s-2h+p+\alpha)$$
$$-\tfrac{15}{16}me\cos(2\sigma_{,}-s+2h-p+\alpha) \quad . \quad . \quad (25)$$

Then substituting from (23), (24), (25), in (12), and dropping the

[1] p in this sense will easily be distinguished from the p used to denote $\cos\frac{1}{2}I$, which latter will, moreover, be shortly discarded.

terms which are merely a reproduction of those already obtained, and neglecting terms in q^2 and q^3, we have

$$\left.\begin{aligned}
X^2-Y^2 &= \tfrac{105}{16}mep^4\cos(2\chi-2\sigma_{,}-s+2h-p)\\
&\qquad -\tfrac{15}{16}mep^4\cos(2\chi-2\sigma_{,}+s-2h+p)\\
XZ &= -\tfrac{105}{16}mep^3q\sin(\chi-2\sigma_{,}-s+2h-p)\\
&\qquad +\tfrac{15}{16}mep^3q\sin(\chi-2\sigma_{,}+s-2h+p)\\
&\qquad +\tfrac{45}{16}mepq(p^2-q^2)[\sin(\chi+s-2h+p)+\sin(\chi-s+2h-p)]\\
\tfrac{1}{3}(X^2+Y^2-2Z^2) &= \tfrac{1}{3}(p^4-4p^2q^4+q^4)\,\tfrac{45}{8}me\cos(s-2h+p)
\end{aligned}\right\}\quad(25)$$

It must be noticed that $\frac{105}{16}\,me$ arises by the addition of the coefficient of the Evection in longitude to three halves of that in the reciprocal of the radius vector; that $\frac{15}{16}\,me$ is the difference of the same two quantities; and that $\frac{45}{8}\,me$ is three times the coefficient in the reciprocal of radius vector. When the development of the lunar theory is carried to higher orders these coefficients differ considerably from the amounts computed from the first term, which alone occurs in the above analysis. Hence, when these coefficients are computed, the full values of the coefficients in longitude and reciprocal of radius vector must be introduced. According to Professor Adams, the full values of the coefficients are, in longitude ·022233, and in c/r ·010022.

The ratio of the mean motions m is about $\frac{1}{13}$, and is therefore a little greater than e, hence me is somewhat greater than e^2. Thus we may abridge (25), and write the expressions thus:—

$$\left.\begin{aligned}
X^2-Y^2 &= \tfrac{105}{16}mep^4\cos(2\chi-2\sigma_{,}-s+2h-p)\\
&\qquad -\tfrac{15}{16}mep^4\cos(2\chi-2\sigma_{,}+s-2h+p)\\
XZ &= -\tfrac{105}{16}mep^3q\sin(\chi-2\sigma_{,}-s+2h-p)\\
\tfrac{1}{3}(X^2+Y^2-2Z^2) &= \tfrac{1}{3}(p^4-4p^2q^2+q^4)\tfrac{45}{8}me\cos(s-2h+p)
\end{aligned}\right\}\quad(26)$$

The equations (26) contain the terms to be added to (20) on account of the Evection.

The Variation.

Treating this inequality in the same way as the Evection, we have

$$l=\sigma_{,}+\tfrac{11}{8}m^2\sin 2(s-h)$$

$$\frac{c\,(1-e^2)}{r}=1+m^2\cos 2(s-h)$$

$$R=1+3m^2\cos 2\,(s-h)$$

$$\Psi(a)=\cos a+\tfrac{3}{2}m^2\,[\cos(2(s-h)+a)+\cos(2(s-h)-a)]$$

$$\Phi(a)=\cos(2\sigma_{,}+a)+\tfrac{23}{8}m^2\cos(2\sigma_{,}+2s-2h+a)$$
$$+\tfrac{1}{8}m^2\cos(2\sigma_{,}-2s+2h+a)$$

Whence we have to a sufficient degree of approximation,

$$\left.\begin{aligned}
X^2-Y^2 &= \tfrac{23}{8}m^2p^4\cos(2\chi-2\sigma_{,}-2s+2h),\quad XZ=0\\
\tfrac{1}{3}(X^2+Y^2-2Z^2) &= \tfrac{1}{3}(p^4-4p^2q^2+q^4)\,3m^2\cos(2s-2h)
\end{aligned}\right\}\quad(27)$$

In this case also the values of the coefficients are actually considerably greater than the amounts as computed from the first terms; and regard must be paid to this, as in the case of the Evection, when the values of the coefficients in the tidal expressions are computed. According to Professor Adams, the full values of the coefficients are, in longitude ·011489, and in c/r ·008249.

We have now obtained in (20), (26), (27), the complete expressions for the X-Y-Z functions in the shape of a series of simple time-harmonics; but they are not yet in a form in which the ordinary astronomical formulæ are applicable.

Further substitutions will now be made, and we shall pass from the potential to the height of tide generated by the forces corresponding to that potential.

The axes fixed in the earth may be taken to have their extremities as follows:

The axis A on the equator in the meridian of the place of observation of the tides; the axis B in the equator 90° east of A; the axis C at the north pole.

Now ξ, η, ζ are the direction-cosines of the place of observation, and if λ be the latitude of that place, we have

$$\xi=\cos\lambda, \quad \eta=0, \quad \zeta=\sin\lambda.$$

Thus

$$\xi^2-\eta^2=\cos^2\lambda, \quad \xi\eta=0, \quad \eta\zeta=0, \quad 2\xi\zeta=\sin 2\lambda, \quad \tfrac{1}{3}(\xi^2+\eta^2-2\zeta^2)=\tfrac{1}{3}-\sin^2\lambda.$$

Then writing a for the earth's radius, the expression (10) for V at the place of observation becomes

$$V=\frac{\tau a^2}{(1-e^2)^3}\left[\tfrac{1}{2}\cos^2\lambda\,(X^2-Y^2)+\sin 2\lambda\, XZ \right.$$
$$\left. +\tfrac{3}{2}\left(\tfrac{1}{3}-\sin^2\lambda\right)\tfrac{1}{3}(X^2+Y^2-2Z^2)\right]$$

The X-Y-Z functions being simple time-harmonics, the principle of forced vibrations allows us to conclude that the forces corresponding to V will generate oscillations in the ocean of the same periods and types as the terms in V, but of unknown amplitudes and phases.

Now let $\mathfrak{X}^2-\mathfrak{Y}^2$, $\mathfrak{X}\mathfrak{Z}$, $\frac{1}{3}(\mathfrak{X}^2+\mathfrak{Y}^2-2\mathfrak{Z}^2)$ be three functions, having respectively similar forms to those of

$$\frac{X^2-Y^2}{(1-e^2)^3}, \quad \frac{XZ}{(1-e^2)^3} \text{ and } \frac{1}{3}\frac{(X^2+Y^2-2Z^2)}{(1-e^2)^3},$$

but differing from them in that the argument of each of the simple time-harmonics has some angle subtracted from it, and that the term is multiplied by a numerical factor.

Then if g be gravity, and h the height of tide at the place of observation we must have

$$h=\frac{\tau a^2}{g}\left[\tfrac{1}{2}\cos^2\lambda\,(\mathfrak{X}^2-\mathfrak{Y}^2)+\sin 2\lambda\,\mathfrak{X}\mathfrak{Z}\right.$$
$$\left.+\tfrac{3}{2}\left(\tfrac{1}{3}-\sin^2\lambda\right)\tfrac{1}{3}(\mathfrak{X}^2+\mathfrak{Y}^2-2\mathfrak{Z}^2)\right] \quad (28)$$

The factor $\dfrac{\tau a^2}{g}$ may be more conveniently written $\frac{3}{2}\dfrac{M}{E}\left(\dfrac{a}{c}\right)^3 a$, where

E is the earth's mass. It has been so chosen that if the equilibrium theory of tides were fulfilled, with water covering the whole earth, the numerical factors in the $\mathfrak{X}$-$\mathfrak{Y}$-$\mathfrak{Z}$ functions would be each unity. The alterations of phase would also be zero, or, with land and sea as in reality, they might be computed by means of the five definite integrals involved in Sir William Thomson's amended equilibrium theory of tides.[1]

The actual results of tidal analysis at any place are intended (see below, § 5) to be presented in a series of terms of the form fH cos $(V+u-\kappa)$, where dV/dt or n, 'the speed,' is the rate of increase of the argument per unit time (say degrees per mean solar hour), and u is a constant. We require, therefore, to present all the terms of the $\mathfrak{X}$-$\mathfrak{Y}$-$\mathfrak{Z}$ functions as cosines with a positive sign. When, therefore, in these functions we meet with a negative cosine we must change its sign and add π to the argument; as the $\mathfrak{X}\mathfrak{Z}$ functions involve sines, we must add $\frac{1}{2}\pi$ to arguments of the negative sines, and subtract $\frac{1}{2}\pi$ from the arguments of the positive sines, and replace sines by cosines. The terms in the $\frac{1}{3}(\mathfrak{X}^2+\mathfrak{Y}^2-2\mathfrak{Z}^2)$ function require special consideration. The function of the latitude being $\frac{1}{3}-\sin^2\lambda$, it follows that when in the northern hemisphere it is high-water north of a certain critical latitude, it is low water on the opposite side of that parallel; and the same is true of the southern hemisphere. The critical latitude is that in which $\sin^2\lambda=\frac{1}{3}$, or in Thomson's amended equilibrium ([1]) theory, where $\sin^2\lambda=\frac{1}{3}(1+\mathfrak{E})$. An approximate evaluation of $\mathfrak{E}$, which depends on the distribution of land and sea, given in § 848 of the second edition of Thomson and Tait's 'Natural Philosophy,' shows that the critical latitudes are 35° N. and S. It will be best to adopt a uniform system for the whole earth, and to regard high-tide and high-water as consentaneous in the equatorial belt, and of opposite meanings outside of the critical latitudes. In this Report we conceive the function always to be written $\frac{1}{3}-\sin^2\lambda$, so that outside of the critical latitudes high-tide is low-water. Accordingly we must add π to the arguments of the negative cosines (if any) which occur in the function $\frac{1}{3}(\mathfrak{X}^2+\mathfrak{Y}^2-2\mathfrak{Z})$.

In continuing the development, the $\mathfrak{X}$-$\mathfrak{Y}$-$\mathfrak{Z}$ functions will be written in the form appropriate to the equilibrium theory, with water covering the whole earth; for the actual case it is only necessary to multiply by the reducing factor, and to subtract the phase alteration κ. As these are unknown constants for each place, they would only occur in the development as symbols of quantities to be deduced from observation. It will be understood, therefore, that in the following schedules 'the argument' is that part of the argument which is derived from theory, the true complete argument being 'the argument' $-\kappa$, where κ is derived from observation.

Following the plan suggested, and collecting results from (20), (26), (27), we have

$$
\begin{aligned}
\mathfrak{X}^2-\mathfrak{Y}^2 = {} & (1-\tfrac{5}{2}e^2)p^4\cos 2(\chi-\sigma_{,}) + (1+\tfrac{3}{2}e^2)\,2p^2q^2\cos 2\chi \\
& \qquad\qquad + \tfrac{7}{2}ep^4\cos(2\chi-3\sigma_{,}+\varpi_{,}) \\
& + \tfrac{1}{2}ep^4\sqrt{\{1-12\tan^2\tfrac{1}{2}I\cos 2\varpi_{,}\}}\cos(2\chi-\sigma_{,}-\varpi_{,}-R+\pi) \\
& + \tfrac{17}{2}e^2p^4\cos(2\chi-4\sigma_{,}+2\varpi_{,}) \\
& + \tfrac{105}{16}mep^4\cos(2\chi-2\sigma_{,}-s+2h-p) \\
& + \tfrac{15}{16}mep^4\cos(2\chi-2\sigma_{,}+s-2h+p+\pi) \\
& + \tfrac{23}{8}m^2p^4\cos(2\chi-2\sigma_{,}-2s+2h) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (29)
\end{aligned}
$$

[1] Thomson and Tait's *Nat. Phil.*, or the Report on Tides for 1876.

$$\mathfrak{X}\mathfrak{Z}=(1-\tfrac{5}{2}e^2)[p^3q\cos(\chi-2\sigma_,+\tfrac{1}{2}\pi)+pq^3\cos(\chi+2\sigma_,-\tfrac{1}{2}\pi)]$$
$$+(1+\tfrac{3}{2}e^2)pq(p^2-q^2)\cos(\chi-\tfrac{1}{2}\pi)$$
$$+\tfrac{7}{2}ep^3q\cos(\chi-3\sigma_,+\varpi_,+\tfrac{1}{2}\pi)$$
$$+ep^3q\sqrt{\{\tfrac{5}{2}+\tfrac{3}{2}\cos 2\varpi_,\}}\cos(\chi-\sigma_,+Q-\tfrac{1}{2}\pi)$$
$$+\tfrac{3}{2}epq(p^2-q^2)\cos(\chi+\sigma_,-\varpi_,-\tfrac{1}{2}\pi)$$
$$+\tfrac{17}{2}e^2p^3q\cos(\chi-4\sigma_,+2\varpi_,+\tfrac{1}{2}\pi)$$
$$+\tfrac{105}{16}mep^3q\cos(\chi-2\sigma_,-s+2h-p+\tfrac{1}{2}\pi)\quad\ldots\ldots\quad(30)$$

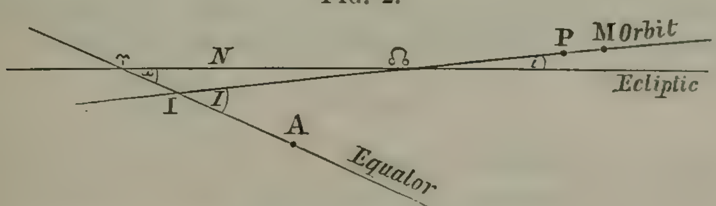
$$\tfrac{1}{3}(\mathfrak{X}^2+\mathfrak{Y}^2-2\mathfrak{Z}^2)=\tfrac{1}{3}(p^4-4p^2q^2+q^4)[1+\tfrac{3}{2}e^2+3e\cos(\sigma_,-\varpi_,)$$
$$+\tfrac{45}{8}me\cos(s-2h+p)+3m^2\cos(2s-2h)]$$
$$+2p^2q^2[(1-\tfrac{5}{2}e^2)\cos 2\sigma_,+\tfrac{7}{2}e\cos(3\sigma_,-\varpi_,)]\quad(31)$$

In these expressions

$$\tan R=\frac{\sin 2\varpi_,}{\tfrac{1}{6}\cot^2\tfrac{1}{2}I-\cos 2\varpi_,},\quad \tan Q=\tfrac{1}{2}\tan\varpi_,$$

The next step is to express the angles χ, $\sigma_,$, $\varpi_,$, each of which increases uniformly with the time, in terms of the sidereal hour-angle or of the local mean time, and of the mean longitudes of the moon, and of the perigee.

FIG. 2.



Let M be the moon in the orbit. A the extremity of the A-axis fixed in the earth.

- g be the sidereal hour-angle.
- N the longitude of the node ☊.
- ν the right ascension of the intersection I.
- ξ the longitude 'in the moon's orbit' of the intersection.
- i the inclination of the moon's orbit to the ecliptic.
- ω the obliquity of the ecliptic.
- s the moon's mean longitude.
- p the mean longitude of the perigee.[1]

Then (Fig. 2) g$=$A♈, $\nu=$♈I, $\xi=$♈☊$-$☊I, $N=$♈☊.

Now $\sigma_,$ and $\varpi_,$ have been defined above as the moon's mean longitude and the longitude of the perigee, both measured in the orbit from the intersection I.

[1] This p will easily be distinguished from the p used above to denote $\cos\frac{1}{2}$ I.

Since $\sigma_{,}-\varpi_{,}$ is the moon's mean anomaly, we have

$$s-p = \sigma_{,}-\varpi_{,}$$

Let p' be the longitude of the perigee, measured from ♈ in the ecliptic.

If P in Fig. 2 be perigee, we have by the ordinary formula for reduction to the ecliptic,

$$☊\mathrm{P}=p'-N+\tfrac{1}{4}\sin^2 i \sin 2(p'-N)$$

But $\varpi_{,}=\mathrm{IP}=\mathrm{I}☊+☊\mathrm{P}=♈☊-\xi+☊\mathrm{P}$

$$=p'-\xi+\tfrac{1}{4}\sin^2 i\sin 2(p'-N)$$

Now $p=p'+\frac{1}{4}\sin^2 i\sin 2(p'-N)$, and therefore

$$\left.\begin{aligned}\varpi_{,}&=p-\xi\\ \sigma_{,}&=s-\xi\end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (32)$$

whence

Again

$$\chi=\mathrm{IA}=\mathrm{A}♈-\mathrm{I}♈=\mathrm{g}-\nu \quad \ldots\ldots\ldots \quad (33)$$

In this formula we suppose g to increase uniformly from the time when the tidal observations begin.

Since in all the tidal observations local mean solar time is used, it will be better to substitute for g in terms of local mean solar time and the sun's mean longitude. Let t be local mean solar time reduced to angle, so that at noon $t=0°$. Let h be the sun's mean longitude; hereafter we shall write p_1 for the longitude of the sun's perigee.

Then we have

$$\chi=t+h-\nu \quad \ldots\ldots\ldots\ldots \quad (34)$$

We shall now substitute from (32) and (34) in the $\mathfrak{X}$-$\mathfrak{Y}$-$\mathfrak{Z}$ functions (29), (30), (31); substitute from them in (28), and express the final result in the form of three schedules (pp. 18, 19, 20).

The schedules are arranged thus. First, there is the general coefficient $\frac{3}{2}\frac{M}{E}\left(\frac{a}{c}\right)^3 a$ which multiplies every term of all the schedules. Secondly, there are general coefficients one for each schedule, viz. $\cos^2\lambda$ for the semi-diurnal terms, $\sin 2\lambda$ for the diurnal, and $\frac{1}{2}-\frac{3}{2}\sin^2\lambda$ for the terms of long period. These three functions of the latitude of the place of observation are the values at that place of three surface spherical harmonic functions, which functions have the maximum value unity, at the equator for the semi-diurnal, in latitude 45° for the diurnal, and at the pole for the terms of long period.

First, in each schedule there is a column of coefficients, functions of I and e (and in two cases also of p).

In the second column is given the mean semi-range of the corresponding term. This is approximately the value of the coefficient in the first column when $I=\omega$. We forestall results given below so far as to state that the mean value is to be found by putting $I=\omega$ in the 'coefficient,' and when the function of I is $\cos^4\frac{1}{2}I$, $\sin I\cos^2\frac{1}{2}I$, $\sin I\sin^2\frac{1}{2}I$, $\sin^2 I$ (in B, iii.) multiplying further by $\cos^4\frac{1}{2}i$; and where the function of I is $\sin^2 I$ (in B, i.) $\sin I\cos I$, $1-\frac{3}{2}\sin^2 I$ multiplying by $1-\frac{3}{2}\sin^2 i$.

Thirdly, there is a column of arguments, linear functions of t, h, s,

p, ν, ξ. In B, i. $2t+(2h-2\nu)$, and in B, ii. $t+(h-\nu)$, are common to all the arguments, and they are written at the top of the column of arguments. The arguments are grouped in a manner convenient for subsequent computations.

Fourthly, there is a column of speeds, being the hourly increase of the arguments in the preceding column, the numerical values of which are added in a last column.

Every term is indicated by the initial letters (see § 1) adopted for the tide to which it corresponds, except in the case of certain unimportant terms to which no initials have been appropriated.

To write down any term: take the general coefficient; the coefficient for the class of tides; the special coefficient, and multiply by the cosine of the argument. The result is a term in the equilibrium tide (with water covering the whole earth). The transition to the actual case by the introduction of a factor and a delay of phase (to be derived from observation) has been already explained.

The solar tides.

The expression for the tides depending on the sun may be written down at once by symmetry. The eccentricity of the solar orbit is so small, being ·01679, that the elliptic tides may be omitted, excepting the larger elliptic semi-diurnal tide.

The lunar schedule is to be transformed by putting $s=h$, $p=p_1$, $\xi=\nu=0$, $\sigma=\eta$, $I=\omega$, $e=e_1$, $\varpi=\varpi_1$. In order that the comparison of the importance of the solar tides with the lunar may be complete, the same general coefficient $\frac{3}{2}\frac{M}{E}\left(\frac{a}{c}\right)^3 a$ will be retained, and the special coefficient for each term will be made to involve the factor τ_1/τ. Here $\tau_1=\frac{3}{2}\frac{\mu S}{c_1^{\,3}}$, S being the sun's mass.

With $E/M=81 5$,

$$\frac{\tau_1}{\tau}=\cdot 46035=\frac{1}{2\cdot 17226}.$$

The schedule [C] of solar tides is given on page 21.

The subsequent schedules [D] and [E] give all the tides of purely astronomical origin contained in the previous developments, arranged first in order of speed, and secondly in order of the magnitude of the coefficient. As most of the observations of the tides are made at places remote from the pole, the coefficients of the tides of long period are written down with a general coefficient $1-3\sin^2 l$ in place of $\frac{1}{2}-\frac{3}{2}\sin^2 l$: that is to say, the spherical harmonic function has the value unity at the equator and two at the pole. In schedule [E] the tides K_1, K_2 originate both from the moon and sun, but the lunar and solar parts are also entered separately.

The coefficients of the evectional and variational tides are computed from the full values to those inequalities.

In the schedule [E] the tides are marked which occur in the 'Tide-predicter' of the Indian Government in its present condition.

Schedule of Lunar Tides [B, i.]

General Coefficient$=\frac{3}{2}\frac{M}{E}\left(\frac{a}{c}\right)^3 a.$

Semi-diurnal Tides; General Coefficient$=\cos^2\lambda$.

Initial	Coefficient	Mean Value of Coefficient	Argument $2t+2(h-\nu)$	Speed	Speed in degrees per m. s. hour
M_2	$\frac{1}{2}(1-\frac{5}{2}e^2)\cos^4\frac{1}{2}I$	·45426	$-2(s-\xi)$	$2(\gamma-\sigma)$	28°·9841042
K_2	$\frac{1}{2}(1+\frac{3}{2}e^2)\frac{1}{2}\sin^2 I$	·03929	—	2γ	30°·0821372
N	$\frac{1}{2}\cdot\frac{7}{2}e\cos^4\frac{1}{2}I$	·08796	$-2(s-\xi)-(s-p)$	$2\gamma-3\sigma+\varpi$	28°·4397296
L	$\frac{1}{2}\cdot\frac{1}{2}e\cos^4\frac{1}{2}I$ $\times\sqrt{\{1-12\tan^2\frac{1}{2}I\cos 2(p-\xi)\}}$	·01257	$-2(s-\xi)+(s-p)-R+\pi$ where $\tan R=\frac{6\sin 2(p-\xi)}{\cot^2\frac{1}{2}I-6\cos 2(p-\xi)}$	$2\gamma-\sigma-\varpi$	29°·5284788
2N	$\frac{1}{2}\cdot\frac{17}{2}e^2\cos^4\frac{1}{2}I$	·01173	$-2(s-\xi)-2(s-p)$	$2\gamma-4\sigma+2\varpi$	27°·8953548
ν	$\frac{1}{2}\cdot\frac{105}{16}me\cos^4\frac{1}{2}I$	·01234† ·01706	$-2(s-\xi)+(s-p)+2h-2s$	$2\gamma-3\sigma-\varpi+2\eta$	28°·5125830
λ	$\frac{1}{2}\cdot\frac{15}{16}me\cos^4\frac{1}{2}I$	·00176† ·00330	$-2(s-\xi)-(s-p)-2h+2s+\pi$	$2\gamma-\sigma+\varpi-2\eta$	29°·4556254
*μ	$\frac{1}{2}\cdot\frac{23}{8}m^2\cos^4\frac{1}{2}I$	·00736† ·01094	$-2(s-\xi)+2h-2s$	$2\gamma-4\sigma+2\eta$	27°·9682084

* Indicated by 2MS as a compound tide. † In these three entries the lower of the two numbers gives the value when the coefficients of the Evection and Variation have their full values as derived from Lunar Theory.

[B, ii.]

Diurnal Tides; General Coefficient = sin 2λ.

Initial	Coefficient	Mean Value of Coefficient	Argument $t+(h-\nu)$	Speed	Speed in degrees per m. s. hour
O	$(1-\frac{5}{2}e^2)\ \frac{1}{2}\sin I\cos^2\frac{1}{2}I$	·18856	$-2(s-\xi)+\frac{1}{2}\pi$	$\gamma-2\sigma$	13°·9430356
OO	$(1-\frac{5}{2}e^2)\ \frac{1}{2}\sin I\sin^2\frac{1}{2}I$	·00812	$+2(s-\xi)-\frac{1}{2}\pi$	$\gamma+2\sigma$	16°·1391016
K_1	$(1+\frac{3}{2}e^2)\ \frac{1}{2}\sin I\cos I$	·18115	$-\frac{1}{2}\pi$	γ	15°·0410686
Q	$\frac{7}{2}e\ \frac{1}{2}\sin I\cos^2\frac{1}{2}I$	·03651	$-2(s-\xi)-(s-p)+\frac{1}{2}\pi$	$\gamma-3\sigma+\varpi$	13°·3986609
M_1	$e\ \frac{1}{2}\sin I\cos^2\frac{1}{2}I$ $\times\sqrt{\{\frac{5}{2}+\frac{3}{2}\cos 2(p-\xi)\}}$	·00522* ·01649	$-(s-\xi)+Q-\frac{1}{2}\pi$ where $\tan Q=\frac{1}{2}\tan(p-\xi)$	$\gamma-\sigma$	14°·4920521
J	$\frac{3}{2}e\ \frac{1}{2}\sin I\cos I$	·01485	$+(s-p)-\frac{1}{2}\pi$	$\gamma+\sigma-\varpi$	15°·5854433
	$\frac{17}{2}e^2\ \frac{1}{2}\sin I\cos^2\frac{1}{2}I$	·00487	$-2(s-\xi)-2(s-p)+\frac{1}{2}\pi$	$\gamma-4\sigma+2\varpi$	12°·8542862
	$\frac{105}{16}me\ \frac{1}{2}\sin I\cos^2\frac{1}{2}I$	·00512† ·00708	$-2(s-\xi)+(s-p)+2h-2s+\frac{1}{2}\pi$	$\gamma-3\sigma-\varpi+2\eta$	13°·4715144

* The first of these two numbers is the mean value of the coefficient of the tide $\gamma-\sigma-\varpi$; the second applies to the tide M_1 compounded from $\gamma-\sigma-\varpi$ and $\gamma-\sigma+\varpi$.

† The lower of these two figures gives the value when the coefficients in the Evection have the full value as derived from the Lunar Theory.

[B, iii.]

Long Period Tides; General Coefficient $\frac{1}{2}-\frac{3}{2}\sin^2\lambda$.

Name or Initial	Coefficient	Mean Value of Coefficient	Argument	Speed	Speed in degrees per m. s. hour
	$(1+\frac{3}{2}e^2)\,\frac{1}{3}\,(1-\frac{3}{2}\sin^2 I)$	·25224**	Of variable part is N, the long. of node	$\frac{dN}{dt}$	19°·34 per annum
Mm	$3e\,.\,\frac{1}{3}\,(1-\frac{3}{2}\sin^2 I)$	·04136	$s-p$	$\sigma-\varpi$	0°·5443747
Evect. monthly	$\frac{45}{8}me\,.\,\frac{1}{3}\,(1-\frac{3}{2}\sin^2 I)$	·00580† ·00755	$-(s-p)+2s-2h$	$\sigma-2\eta+\varpi$	0°·4715211
*	$3m^2\,.\,\frac{1}{3}\,(1-\frac{3}{2}\sin^2 I)$	·00422† ·00621	$2\,(s-h)$	$2\,(\sigma-\eta)$	1°·0158958
Mf	$(1-\frac{5}{2}e^2)\,\frac{1}{2}\sin^2 I$	·07827	$2(s-\xi)$	2σ	1°·0980330
Termensual	$\frac{5}{2}e\,.\,\frac{1}{2}\sin^2 I$	·01516	$(s-p)+2\,(s-\xi)$	$3\sigma-\varpi$	1°·6424077

* Indicated by MSf as a compound tide.

** The mean value of this coefficient is $\frac{1}{3}\,(1+\frac{3}{2}\,e^2)\cdot(1-\frac{3}{2}\,\sin^2 i)\,(1-\frac{3}{2}\,\sin^2\omega)=·25$, and the variable part is approximately $-(1+\frac{3}{2}e^2)\sin i\cos i\sin\omega\cos\omega\cos N=-·0328\cos N$.

† The lower of these figures give the value when the coefficients in the Evection and Variation have their full values as derived from the Lunar Theory.

[C.]

Schedule of Solar Tides.

Solar Tides; General Coefficient$=\frac{3}{2}\frac{M}{E}\left(\frac{a}{c}\right)^3 a$.

Initial	Coefficient	Value of Coefficient	Argument	Speed	Speed in degrees per m. s. hour
[i.] *Semi-diurnal Tides; General Coefficient*$=\cos^2\lambda$.					
S_2	$\frac{\tau_1}{\tau}(1-\frac{5}{2}e_1^2)\,\frac{1}{2}\cos^4\frac{1}{2}\omega$	·21137	$2t$	$2(\gamma-\eta)$	30°·000000
K_2	$\frac{\tau_1}{\tau}(1+\frac{3}{2}e_1^2)\,\frac{1}{4}\sin^2\omega$	·01823	$2t+2h$	2γ	30°·0821372
T	$\frac{\tau_1}{\tau}\cdot\frac{1}{2}\cdot\frac{7}{2}e_1\cos^4\frac{1}{2}\omega$	·01243	$2t-(h-p_1)$	$2\gamma-3\eta$	29°·9589314
[ii.] *Diurnal Tides; General Coefficient*$=\sin 2\lambda$.					
P	$\frac{\tau_1}{\tau}(1-\frac{5}{2}e_1^2)\,\frac{1}{2}\sin\omega\cos^2\frac{1}{2}\omega$	·08775	$t-h+\frac{1}{2}\pi$	$\gamma-2\eta$	14°·9589314
K_1	$\frac{\tau_1}{\tau}(1+\frac{3}{2}e_1^2)\,\frac{1}{2}\sin\omega\cos\omega$	·08407	$t+h-\frac{1}{2}\pi$	γ	15°·0410686
[iii.] *Long Period Tides; General Coefficient*$=\frac{1}{2}-\frac{3}{2}\sin^2\lambda$.					
Ssa	$\frac{\tau_1}{\tau}(1-\frac{5}{2}e_1^2)\frac{1}{2}\sin^2\omega$	·03643	$2h$	2η	0°·0821372

[D.]

Schedule of Speeds in Degrees per Mean Solar Hour.

Semi-diurnal Tides		Diurnal Tides		Long-period Tides	
Initial	Speed	Initial	Speed	Initials	Speed
K_2	30°·0821372	OO	16°·1391016	$3\sigma-\varpi$	1°·6424077
S_2	30°·000000	J	15°·5854433	Mf	1°·0980330
T	29°·9589314	K_1	15°·0410686	$2(\sigma-\eta)$	1°·0158958
L	29°·5284788	P	14°·9589314	Mm	0°·5443747
λ	29°·4556254	M_1	14°·4920521	$\sigma-2\eta+\varpi$	0°·4715211
M_2	28°·9841042	O	13°·9430356	Ssa	0°·0821372
ν	28°·5125830	$\gamma-3\sigma-\varpi+2\eta$	13°·4715144		
N	28°·4397296	Q	13°·3986609		
μ	27°·9682084	$\gamma-4\sigma+2\varpi$	12°·8542862		
2N	27°·8953548				

Besides these there is the tide initialled R, with speed $2\gamma-\eta=30°\cdot0410686$, which may be neglected.

The variational tides μ and $2(\sigma-\eta)$ have the same speeds respectively as the compound tides 2MS and MSf, and they will occur again when we come to those tides in § 4.

[E.]

Schedule of Theoretical Importance.

Initial	Indian Predicter	Coefficient	Coefficient in terms of $M_2=1$	Initial	Indian Predicter	Coefficient	Coefficient in terms of $M_2=1$
M_2	M_2	·45426	1·00000	ν	ν	·01706	·03756
K_1	K_1	·26522	·58385	M_1	—	·01649	·03630
S_2	S_2	·21137	·46531	J	J	·01485	·03269
O	O	·18856	·41509	L	L	·01257	·02767
[lunar K_1	. . . .	·18115	·39878]	T	—	·01243	·02736
N	N	·08796	·19363	2N	—	·01173	·02582
P	P	·08775	·19317	variational μ	—	·01094	·02408
[solar K_1	. . . .	·08407	·18507]	OO	—	·00812	·01788
K_2	K_2	·05752	·12662	$3\sigma-\varpi$	—	·00758	·01669
[lunar K_2	. . . .	·03929	·08649]	$\gamma-3\sigma-\varpi+2\eta$	—	·00708	·01559
Mf	—	·03914	·08616	$\gamma-4\sigma+2\varpi$	—	·00487	·01072
Q	Q	·03651	·08037	$\sigma-2\eta+\varpi$	—	·00378	·00832
Mm	—	·02068	·04552	variational $2(\sigma-\eta)$	—	·00330	·00726
[solar K_2	. . . .	·01823	·04013]	λ	λ	·00311	·00685
Ssa	semi-annual	·01822	·04011				

A tide of greater importance than some of those retained here is that referred to where the approximation with regard to I was introduced, viz. with speed $2\gamma+\sigma-\varpi$; the value of its coefficient is ·00323. There is also the larger variational diurnal tide, which has been omitted: it would have a coefficient ·00450; also an evectional termensual tide, $\frac{105}{16}me\ \frac{1}{2}\sin^2 I\cos(3s-2h+p)$, with coefficient of magnitude ·00292. All other tides in a complete development as far as the second order of small quantities, without any approximation as to the obliquity of the lunar orbit, would have smaller coefficients than those comprised in the above list. Such a development has been made by Professor J. C. Adams, and the values of all the coefficients computed therefrom, in comparison with the above.

Besides the tides above enumerated, the predicter of the India Office also has the over-tides M_4 and M_6, of speeds $4(\gamma-\sigma)$, $6(\gamma-\sigma)$, and the compound tides 2MS, 2SM, MS, of speeds $2\gamma-4\sigma+2\eta$, $2\gamma+2\sigma-4\eta$, $4\gamma-2\sigma-2\eta$, and the meteorological tides S_1, Sa, of speeds $\gamma-\eta$, η.

If this schedule is worth anything, it seems probable that the India Office predicter would do better with some other term substituted for λ.

If further examination of the tidal records should show that the tide M_1 is in reality regular, it should be introduced.

§ 3. *Tides Depending on the Fourth Power of the Moon's Parallax.*

The potential corresponding to these tides is

$$V=\frac{\mu M}{r^4}\rho^3\left(\tfrac{5}{2}\cos^3 \mathrm{PM}-\tfrac{3}{2}\cos \mathrm{PM}\right).$$

We may obviously neglect the eccentricity of the lunar orbit, and it will appear below, when the principal terms are evaluated, that the declinational tides may be safely omitted.

By these approximations we may put $r=c$, and $M_3=0$, and neglect the terms in M_1, M_2 which involve q^2. Following the same plan as in the previous development of § 2, we have, when $M_3=0$,

$$\begin{aligned}V\div\frac{\mu M}{c^4}\rho^3= &\ \tfrac{5}{8}(\xi^3-3\xi\eta^2)(M_1{}^3-3M_1M_2{}^2)+\tfrac{5}{8}(\eta^3-3\xi^2\eta)(M_2{}^3-3M_1{}^2M_2)\\ &+\tfrac{3}{8}(\xi^3+\xi\eta^2-4\xi\zeta^2)(M_1{}^3+M_1M_2{}^2)\\ &+\tfrac{3}{8}(\xi^2\eta+\eta^3-4\eta\zeta^2)(M_1{}^2M_2+M_2{}^3)\end{aligned}$$

The four functions of ξ, η, ζ, in this expression are surface spherical harmonics of the third order, and therefore, corresponding to these four terms, there will be four tides of the types determined by those functions.

Now, we have approximately

$$M_1=p^2\cos(\chi-l),\quad M_2=-p^2\sin(\chi-l).$$

From which we have

$$M_1{}^3-3M_1M_2{}^2=p^6\cos 3(\chi-l)$$
$$M_1{}^3+M_1M_2{}^2=p^6\cos(\chi-l)$$

When $\eta=0$; $\xi^3-3\xi\eta^2=\cos^3\lambda$, $\xi^3+\xi\eta^2-4\xi\zeta^2=\cos\lambda\,(1-5\sin^2\lambda)$.

Then, following the same procedure as before, we have for the height of tide

$$h=\tfrac{3}{2}\frac{M}{E}\left(\frac{a}{c}\right)^3\frac{a^2}{c}\left[\tfrac{5}{12}\cos^3\lambda\,.\,p^6\cos 3\,(\chi-l)\right.$$
$$\left.+\tfrac{1}{12}\cos\lambda\,(1-5\sin^2\lambda)\,.\,p^6\cos\,(\chi-l)\right]\quad.\quad(35)$$

Now, $\cos\lambda(5\sin^2\lambda-1)$ has its maximum value $\frac{16}{3\sqrt{15}}$ when $\cos\lambda=\frac{2}{15}\sqrt{15}$: that is to say, when $\lambda=58°\,54'$; thus we may write (35)

$$h=\tfrac{3}{2}\frac{M}{E}\left(\frac{a}{c}\right)^3 a\left[\cos^3\lambda\,.\,\tfrac{5}{12}\left(\frac{a}{c}\right)\cos^6\tfrac{1}{2}I\,.\cos\,[3t+3(h-\nu)-3\,(s-\xi)]\right.$$

$$\left.+\tfrac{3}{16}\sqrt{15}\cos\lambda(1-5\sin^2\lambda)\tfrac{4}{135}\sqrt{15}\left(\frac{a}{c}\right)\cos^6\tfrac{1}{2}I\cos[t+(h-\nu)-(s-\xi)]\right](36)$$

In this expression observe that there is the same 'general coefficient' outside [ ] as in the previous development; that the spherical harmonics $\cos^3\lambda$, $\frac{3}{16}\sqrt{15}\cos\lambda\,(5\sin^2\lambda-1)$ have the maximum values unity, the first at the equator and the second in latitude 58° 54′. The 'speeds' of these two tides are respectively $3\,(\gamma-\sigma)$ or 43°·4761563 per mean solar hour, and $\gamma-\sigma$, or 14°·4920521 per mean solar hour.

The coefficient of the tide $3(\gamma-\sigma)$, which is comparable with those in the previous schedules [B], [C], [E], is

$$\tfrac{5}{12}\left(\frac{a}{c}\right)\cos^6\tfrac{1}{2}I,$$

and the mean value of this function multiplied by $\cos 3\,(\nu-\xi)$ is ·00599; also the coefficient of the tide $(\gamma-\sigma)$, likewise comparable with previous coefficients, is

$$\tfrac{4}{135}\sqrt{15}\left(\frac{a}{c}\right)\cos^6\tfrac{1}{2}I,$$

and the mean value of this function multiplied by $\cos\,(\nu-\xi)$ is ·00165.

The expression for the tides is written in the form applicable to the equatorial belt bounded by latitudes 26° 34′ N. and S. (viz. where $\sin l=\frac{1}{5}\sqrt{5}$). Outside of this belt, what may be called high tide, will correspond with low water. The distribution of land on the earth will probably, however, seriously disturb the latitude of evanescent tide.

It must be noticed that the $\gamma-\sigma$ tide is comparatively small in the equatorial belt, having at the equator only $\frac{3}{8}$ of its value in latitude 58° 54′.

Referring to the schedule [E] of theoretical importance, we see that the ter-diurnal tide M_3 would come in last but four on the list, and the diurnal tide M_1 (with *rigorous* speed $\gamma-\sigma$) would only be about a half of the synodic fortnightly variational tide.

It thus appears that the ter-diurnal tide is smaller than some of the tides not included in our approximation, and that the diurnal tide should certainly be negligeable.

The value of the M_3 tide, however, is found with scarcely any trouble, from the numerical analysis of the tidal observations, and therefore it is proposed that it should still be evaluated.

§ 4. *Meteorological Tides, Over-tides, and Compound Tides.*

Meteorological Tides.

A rise and fall of water due to regular day and night breezes, prevalent winds, rainfall and evaporation, is called a meteorological tide.

All tides whose period is an exact multiple or sub-multiple of a mean solar day, or of a tropical year, are affected by meteorological conditions. Thus all the tides of the principal solar astronomical series S, with speeds $\gamma-\eta$, $2(\gamma-\eta)$, $3(\gamma-\eta)$, &c., are subject to more or less meteorological perturbation. Although the diurnal elliptic tide, S_1 or $\gamma-\eta$, the semi-annual and annual tides of speeds 2η and η, are all probably quite insensible as arising from astronomical causes, yet they have been found of sufficient importance to be included on the tide-predicter.

The annual and semi-annual tides are of enormous importance in some rivers; in such cases the ter-annual tide (3η) is probably also important, although no harmonic analysis has been as yet made for it.

In the reduction of these tides the arguments of the S series are t, $2t$, $3t$, &c., and of the annual, semi-annual, ter-annual tides are h, $2h$, $3h$. As far as can be foreseen, the magnitudes of these tides will be constant from year to year.

Over-tides.

When a wave runs into shallow water its form undergoes a progressive change as it advances; the front slope generally becomes steeper and the back slope less steep. The most striking example of such a change is when the tide runs up a river in the form of a 'bore.'

A wave which in deep water presented an approximately simple harmonic contour departs largely from that form when it has run into shallow water. Thus in rivers the rise and fall of the water is not even approximately a simple harmonic motion. From the nature of harmonic analysis we are, however, able to represent the motion by simple harmonic oscillations, and thus to give the non-harmonic rise and fall of tide in shallow water it is necessary to introduce a series of over-tides whose speeds are double, triple, quadruple the speed of the fundamental astronomical tide.

The only tides, in which it has hitherto been thought necessary to represent this change of form in shallow water, belong to the principal lunar and principal solar series. Thus, besides the fundamental astronomical tides M_2 and S_2, the over-tides M_4, M_6, M_8, and S_4, S_6 have been deduced by harmonic analysis.

The height of the fundamental tide M_2 varies from year to year, according to the variation in the obliquity of the lunar orbit, and this variability is represented by the coefficient $\cos^4 \frac{1}{2} I$. It is probable that the variability of M_4, M_6, M_8, will be represented by the square, cube and fourth power of that coefficient.

The law connecting the phase of an over-tide with the height of the fundamental tide is unknown, and under these circumstances it is only possible to make the argument of the over-tide a multiple of the argument of the fundamental, with a constant subtracted. If that constant is found to be the same from year to year, then it will be known that the phase of an over-tide is independent of the height of the fundamental tide.

The following schedule gives the over-tides which must be taken into consideration, the notation being the same as before:—

[F.]

Schedule of Over-tides.

Tide	Coefficient	Argument	Speed	Speed in degrees per m. s. hour
M_4	$(\cos^4 \frac{1}{2} I)^2$	$4t+4(h-\nu)-4(s-\xi)$	$4\gamma-4\sigma$	57°·9682082
M_6	$(\cos^4 \frac{1}{2} I)^3$	$6t+6(h-\nu)-6(s-\xi)$	$6\gamma-6\sigma$	86°·9523126
M_8	$(\cos^4 \frac{1}{2} I)^4$	$8t+8(h-\nu)-8(s-\xi)$	$8\gamma-8\sigma$	115°·9364164
S_4	1	$4t$	$4\gamma-4\eta$	60°·0000000
S_6	1	$6t$	$6\gamma-6\eta$	90°·0000000

It will be understood that here, as elsewhere, the column of arguments only gives that part of the argument which is derived from theory, and the constant to be subtracted from the argument is derivable from observation. It is necessary to have recourse also to observation to determine whether the suggested law of variability in the magnitude of the M over-tides holds good.

Compound Tides.

When two waves of different speeds are propagated in the same water the vertical displacement at the surface is generally determined with sufficient accuracy by summing the displacements due to each wave separately. If, however, the height of the waves is not a small fraction of the depth of the water, the principle of superposition leads to inaccuracy, and it becomes necessary to take into consideration the squares and products of the displacements.

It may be shown that the result of the interaction of two waves is represented by introducing two simple harmonic waves, whose speeds are the sum and the difference of those of the interacting waves. When the interacting waves are tidal these two resultant waves may be called compound tides. They are found to be of considerable importance in estuaries.

A compound tide being derived from the consideration of the product of displacements, we may form an index number, indicative of the probable importance of each compound tide by multiplying together the semi-ranges of the component tides.

Probably the best way of searching at any station for the compound tides, which are likely to be important, would be to take the semi-ranges of the five or six largest tides at that station and to form index numbers of importance by multiplying the semi-ranges together two and two. Since these index numbers have no absolute magnitudes, we may omit the decimal point in forming them. Having selected as many of these combinations, in order of importance as may be thought expedient, the arguments of the compound tides are to be found by adding and subtracting the arguments of the components taken in pairs.

[G.]

Schedule of Speeds arising out of Combinations.

	K_1	S_2	O	N	M_4	S_4
M_2	$3\gamma-2\sigma$ $\gamma-2\sigma$ (O)	$4\gamma-2\sigma-2\eta$ $2\sigma-2\eta$	$3\gamma-4\sigma$ γ (K_1)	$4\gamma-5\sigma+\varpi$ $\sigma-\varpi$ (Mm)	—	$6\gamma-2\sigma-4\eta$ $2\gamma+2\sigma-4\eta$
K_1	—	$3\gamma-2\eta$ $\gamma-2\eta$ (P)	$2\gamma-2\sigma$ (M_2) 2σ (Mf)	$3\gamma-3\sigma+\varpi$ $\gamma-3\sigma+\varpi$ (Q)	$5\gamma-4\sigma$ $3\gamma-4\sigma$ (bis)	$5\gamma-4\eta$ $3\gamma-4\eta$
S_2	—	—	$3\gamma-2\sigma-2\eta$ $\gamma+2\sigma-2\eta$	$4\gamma-3\sigma+\varpi-2\eta$ $3\sigma-\varpi-2\eta$	$6\gamma-4\sigma-2\eta$ $2\gamma-4\sigma+2\eta$	—
O	—	—	—	$3\gamma-5\sigma+\varpi$ $\gamma-\sigma+\varpi$ (M_1)	$5\gamma-6\sigma$ $3\gamma-2\sigma$ (bis)	$5\gamma-2\sigma-4\eta$ $3\gamma+2\sigma-4\eta$
N	—	—	—	—	$6\gamma-7\sigma+\varpi$ $2\gamma-\sigma-\varpi$ (L)	$6\gamma-3\sigma+\varpi-4\eta$ $2\gamma+3\sigma-\varpi-4\eta$

In the general case it is only possible to take the tides which the previous schedules have shown usually to be large, and to form a list of compound speeds, with index numbers derived from the multiplication together of the mean values of the coefficients of the astronomical tides. The tides selected here will be M_2, K_1, S_2, O, and N; but to these we shall add M_4 and S_4, although it will not be possible to affix index numbers to combinations involving them.

The schedule [G] gives the speeds of the compound tides. In many cases it will be observed that the compound tide has itself a speed identical with that of an astronomical or meteorological tide. These cases are indicated by the addition of the initial after the speed in question. We thus learn that the tides O, K_1, Mm, P, M_2, Mf, Q, M_1, L will be liable to perturbation in shallow water.

The schedule [G] contains 36 speeds of compound tides: 9 of these fall into the category of astronomical or meteorological tides, 2 are repeated twice, and of the remaining 25 we need only consider, say, the twelve most important.

If either or both the component tides are of lunar origin, the height of the compound tide will change from year to year, and will probably vary proportionally to the product of the coefficients of the component tides.

For the purpose of properly reducing the numerical value of the compound tides, we require not merely the speed, but also the argument.

The following schedule gives the index of importance, argument and speed of the compound tides.

The coefficients are the products of the coefficients of the two tides to be compounded.

[H.]

Schedule of Compound Tides.

Index of Importance	Initials	Arguments combined	Speed	Speed in degrees per m. s. hour
1205 —	MK	M_2+K_1 M_4-O	$3\gamma-2\sigma$	44°·0251728
960	MS	M_2+S_2	$4\gamma-2\sigma-2\eta$	58°·9841042
960	MSf	S_2-M_2	$2\sigma-2\eta$	1°·0158958
857 —	2MK	M_2+O M_4-K_1	$3\gamma-4\sigma$	42°·9271398
561	—	S_2+K_1	$3\gamma-2\eta$	45°·0410686
400	MN	M_2+N	$4\gamma-5\sigma+\varpi$	57°·4238338
399	—	S_2+O	$3\gamma-2\sigma-2\eta$	43°·9430356
399	—	S_2-O	$\gamma+2\sigma-2\eta$	16°·0569644
—	2SM	S_4-M_2	$2\gamma+2\sigma-4\eta$	31°·0158958
—	—	M_2+S_4	$6\gamma-2\sigma-4\eta$	88°·9841042
—	2MS	M_4-S_2	$2\gamma-4\sigma+2\eta$	27°·9682084
—	—	M_4+S_2	$6\gamma-4\sigma-2\eta$	87°·9682084

As in the case of the over-tides, the law of variability of the amplitudes of compound tides in various years is only to be tested by observation.

It will be noticed that in two cases an over-tide of one speed arises in more than one way, and accordingly different parts of it have different arguments and coefficients. In these cases the utilisation of the results of

one year for prediction in future years can only be made by dividing up the compound tide into several parts, according to its theoretical origin. In order to do this it is necessary that the law should be known which connects the heights of a summation and a difference compound tide. A like difficulty arises from the fact that MSf and 2SM are also variational tides.

In practice, however, the compound tide will generally be so small that we may probably treat it as though it arose entirely in one way: and accordingly it is proposed to treat the tides $3\gamma-2\sigma$ or MK, and $3\gamma-4\sigma$ or 2MK, as though they arose entirely from M_2+K_1, M_4-K_1 respectively, and MSf and 2SM as though they were entirely compound tides.

§ 5. *The Method of Reduction of Tidal Observations.*

THE printed tabular forms on which the numerical harmonic analysis of the tides is carried out are arranged so that the series of observations to be analysed is supposed to begin at noon, or 0^h, of the first day, and to extend for a year from that time. It has not been found practicable to arrange that the first day shall be the same at all the ports of observation.

Supposing n to be the speed of any tide in degrees per mean solar hour, and t to be mean solar time elapsing since 0^h of the first day; then the immediate result of the harmonic analysis is to obtain A and B, two heights (estimated in feet and tenths) such that the height of this tide at the time t is given by

$$A \cos nt + B \sin nt.$$

The question then arises as to what further reductions it will be convenient to make, in order to present the results in the most convenient form.

First, let us put $R=\sqrt{(A^2+B^2)}$, and $\tan \zeta=\frac{B}{A}$, then the tide is represented by

$$R \cos (nt-\zeta).$$

In this form R is the semi-range of the tide in British feet, and ζ is an angle such that ζ/n is the time elapsing after 0^h of the first day until it is high-water of this particular tide.

It is obvious that ζ may have any value from 0° to 360°, and that the results of the analysis of successive years of observation will not be comparable with one another, when presented in this form.

Secondly, let us suppose that the results of the analysis are to be presented in a number of terms of the form

$$fH \cos (V+u-\kappa).$$

Here V is a linear function of the moon's and sun's mean longitudes, the mean longitude of the moon's and sun's perigees, and the local mean solar time at the place of observation, reduced to angle at 15° per hour. V increases uniformly with the time, and its rate of increase per mean solar hour is the n of the first method, and is called the 'speed' of the tide.

It is supposed that u stands for a certain function of the longitude of the node of the lunar orbit at an epoch half a year later than 0^h of the

first day. Strictly speaking, u should be taken as the same function of the longitude of the moon's node, varying as the node moves; but as the variation is but small in the course of a year, u may be treated as a constant and put equal to an average value for the year, which average value is taken as the true value of u at exactly mid-year. Together $V+u$ constitutes that function which has been tabulated as 'the argument' in the schedules B, C, F, H.

Since $V+u$ are together the whole argument according to the equilibrium theory of tides, with sea covering the whole earth, it follows that κ/n is the lagging of the tide which arises from kinetic action, friction of the water, imperfect elasticity of the earth, and the distribution of land.

It is supposed that H is the mean value in British feet of the semi-range of the particular tide in question.

f is a numerical factor of augmentation or diminution, due to the variability of the obliquity of the lunar orbit. The value of f is the ratio of 'the coefficient' in the column of coefficients of the preceding schedules to the mean value of the same term. For example, for all the solar tides f is unity, and for the principal lunar tide M_2, f is equal to $\cos^4 \frac{1}{2}I/\cos^4 \frac{1}{2}\omega \cos^4 \frac{1}{2}i$; for as we shall see below, the mean value of this term has a coefficient $\cos^4 \frac{1}{2}\omega \cos^4 \frac{1}{2}i$.

It is obvious, then, that, if the tidal observations are consistent from year to year, H and κ should come out the same from each year's reductions. It is only when the results are presented in such a form as this that it will be possible to judge whether the harmonic analysis is presenting us with satisfactory results. This mode of giving the tidal results is also essential for the use of the tide-predicting machine.

We must now show how to determine H and κ from R and ζ.

It is clear that $H=R/f$, and the mode of determination of f from the schedules has been explained above, although the proof has been deferred.

If $V_\circ$ be the value of V at 0^h of the first day, then clearly

$$-\zeta=V_\circ+u-\kappa.$$

So that

$$\kappa=\zeta+V_\circ+u.$$

Thus the rule for the determination of κ is: *Add to the value of ζ the value of the argument at 0^h of the first day.*

It is suggested that it will henceforth be advisable to tabulate R and ζ, so as to give the results of harmonic analysis in the form $R\cos(nt-\zeta)$; and also H and κ, so as to give it in the form $f H \cos(V+u-\kappa)$, when the results will be comparable from year to year.

A third method of presenting tidal results will be very valuable for the discussion of the theory of tidal oscillations, although it is doubtful whether it will at present be worth while to tabulate the results in this proposed form. This method is to substitute for the H of the second method FK, where F is the mean value of the coefficient as tabulated in the column of coefficients in the schedules—for example, in the case of M_2 we should have $F=\frac{1}{2}(1-\frac{5}{2}e^2)\cos^4\frac{1}{2}\omega\cos^4\frac{1}{2}i$, and in the case of S_2 we should have $F=\frac{\tau_1}{\tau}\cdot\frac{1}{2}\cos^4\frac{1}{2}\omega$. When this process is carried out it will enable us to compare together the several K's corresponding to each of the three classes of tides, but not the several classes *inter se*.

It might perhaps be advisable to proceed still further and to purify K of the coefficient $\frac{3}{2}\frac{M}{E}\left(\frac{a}{c}\right)^3 a$, and of the function of the latitude, viz. $\cos^2\lambda$, $\sin 2\lambda$, $\frac{1}{2}-\frac{3}{2}\sin^2\lambda$, as the case may be. Then we should simply be left with a numerical factor as a residuum, which would represent the augmentation above or diminution below the equilibrium value of the tide. This further reduction may, however, be left out of consideration for the present, since it is superfluous for the proper presentation of the results of harmonic analysis.

For the purpose of using the tide-predicting machine the process of determining H and κ from R and ζ has simply to be reversed, with the difference that the instant of time to which the argument is to refer is 0^h of the first day of the new year, and we must take note of the different value of u and f for the new year. Thus supposing V_1 to be the value of V at 0^h of the first day of the year to which the predictions are to apply, and u_1, f_1, the values of u and f half a year after that 0^h, we have

$$R=f_1 H$$
$$\zeta=\kappa-(V_1+u_1)$$

This value of R will give the proper throw of the crank of the tide-predicter, and ζ will give the angle at which the crank is to be set. Mr. Roberts states, however, that the subtraction, in the predicter of the India Office, of V_1+u_1 from κ is actually performed on the machine, one index being set at κ and the other at V_1+u_1.

We learn also from him that one portion of the term u_1 has been systematically neglected up to the present time: namely, that part which arises in the form $\nu-\xi$ or its multiples. If in the schedules above we were to write $\xi=\nu$ throughout we should arrive at the rule by which the tide-predicter has hitherto been used.

The above statement of procedure is applicable to nearly all the tides, but there are certain tides, viz. K_1, K_2, which have their origins jointly in the tide-generating forces of the moon and sun; also the tides L and M_1 which are rendered complex from the fact that the tidal analysis only extends over a year.

Treatment of the Sidereal Diurnal and Semi-diurnal Tides K_1, K_2.—The expression for the whole K_1 tide of luni-solar origin must, as we see from the schedules B and C, § 3, be of the form

$$M\cos(t+h-\tfrac{1}{2}\pi-\nu-\kappa)+S\cos(t+h-\tfrac{1}{2}\pi-\kappa) \quad . \quad . \quad (39)$$

If now we put

$$\left.\begin{aligned} R^2&=M\{1+\left(\frac{S}{M}\right)^2+2\frac{S}{M}\cos\nu\}^{\frac{1}{2}} \\ \tan\nu'&=\frac{\sin\nu}{\cos\nu+S/M}\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (40)$$

these two terms may be written

$$R\cos(t+h-\tfrac{1}{2}\pi-\nu'-\kappa).$$

If h_0 be the sun's mean longitude at 0^h of the first day, $t+h-h_0$ is equal to γt, where t is now mean solar time measured from that 0^h and *not* reduced to angle.

Hence if we write

$$\zeta=\kappa+\tfrac{1}{2}\pi-h_0+\nu' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

the two terms become

$$R \cos(\gamma t - \zeta).$$

But this is the form in which the results of harmonic analysis for the total K_1 tide is expressed in the first method.

From (41) we have

$$\kappa = \zeta + (h_\circ - \tfrac{1}{2}\pi) - \nu' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

In this formula $h_\circ - \frac{1}{2}\pi$ is $V_\circ$ for the solar K_1 tide, and ν' is a complex function of the longitude of the moon's node, to be computed (as explained below) from the second of (40).

We must now consider the coefficient f.

If $M_\circ$ be the mean value of the lunar K_1 tide, then we know that its ratio to M should according to theory be given by

$$\frac{M}{M_\circ} = \frac{\sin I \cos I}{\sin \omega \cos \omega (1 - \frac{3}{2} \sin^2 i)}.$$

The ratio of M to S should also according to theory be given by

$$\frac{M}{S} = \frac{\tau(1 + \frac{3}{2}e^2) \sin I \cos I}{\tau_1(1 + \frac{3}{2}e_1^2) \sin \omega \cos \omega}.$$

We must therefore put the coefficient

$$\left.\begin{aligned} f &= \frac{\left\{1 + \left(\frac{S}{M}\right)^2 + 2\frac{S}{M} \cos \nu\right\}^{\frac{1}{2}}}{1 + \frac{S_\circ}{M_\circ}} \\ \text{where} \quad \frac{S_\circ}{M_\circ} &= \frac{\tau_1 (1 + \frac{3}{2}e_1^2)}{\tau(1 + \frac{3}{2}e^2)} \cdot \frac{1}{(1 - \frac{3}{2} \sin^2 i)} \\ \frac{S}{M} &= \frac{S_\circ}{M_\circ} \frac{\sin \omega \cos \omega (1 - \frac{3}{2} \sin^2 i)}{\sin I \cos I} \end{aligned}\right\} \quad . \quad . \quad . \quad (43)$$

f is clearly a complex function of the longitude of the moon's node to be computed as shown below.

The reversal of the process of reduction for the use of the instrument for prediction is obvious.

In the case of the K_2 semi-diurnal tide, if we follow exactly the same process, and put

$$\left.\begin{aligned} \tan 2\nu'' &= \frac{\sin 2\nu}{\cos 2\nu + S/M} \\ f &= \frac{\left\{1 + \left(\frac{S}{M}\right)^2 + 2\frac{S}{M} \cos 2\nu\right\}^{\frac{1}{2}}}{1 + \frac{S_\circ}{M_\circ}} \\ \text{where} \quad \frac{S_\circ}{M_\circ} &= \frac{\tau_1 (1 + \frac{3}{2}e_1^2)}{\tau(1 + \frac{3}{2}e^2)} \cdot \frac{1}{(1 - \frac{3}{2} \sin^2 i)} \\ \frac{S}{M} &= \frac{S_\circ}{M_\circ} \frac{\sin^2 \omega (1 - \frac{3}{2} \sin^2 i)}{\sin^2 I} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (44)$$

the argument of the K_2 tide is $2t+2h-2\nu''$, and f is the factor for reduction.

The numerical value of $\frac{S_o}{M_o}$ both for K_1 and K_2 is ·46407.

It appears that in using the tide-predicter Mr. Roberts has been hitherto using a process which is obviously incorrect, although the incorrectness has probably only led to very small errors. He has divided the R of the K_1 tide into two parts proportional to the O and P tides respectively, as deduced for the same year by the harmonic analysis for those tides. This process is incorrect in one respect, and not absolutely satisfactory in another. It is incorrect, because it is equivalent to the treatment of ν as zero in the formula

$$R^2=M^2+S^2+2MS\cos\nu\,;$$

and it is unsatisfactory, because the theoretical ratio of O to P is

$$\frac{\tau\,(1-\frac{5}{2}e^2)\sin I\cos^2\frac{1}{2}I}{\tau_1\,(1-\frac{5}{2}e_1{}^2)\sin\omega\cos^2\frac{1}{2}\omega},$$

whereas the ratio of the lunar to the solar K_1 is

$$\frac{\tau\,(1+\frac{3}{2}e^2)\sin 2I}{\tau_1\,(1+\frac{3}{2}e_1{}^2)\sin 2\omega}.$$

Again, he has divided R of K_2 into two parts proportional to the M_2 and S_2 tides. This is again incorrect. The incorrectness arises from a similar treatment of ν as zero, and because the ratio of M_2 to S_2 is

$$\frac{\tau\,(1-\frac{5}{2}e^2)\cos^4\frac{1}{2}I}{\tau_1\,(1-\frac{5}{2}e_1{}^2)\cos^4\frac{1}{2}\omega},$$

whereas the ratio of the lunar to the solar K_2 is

$$\frac{\tau\,(1+\frac{3}{2}e^2)\sin^2 I}{\tau_1(1+\frac{3}{2}e_1{}^2)\sin^2\omega}.$$

Moreover, the S_2 tide is probably liable to meteorological disturbance.

The Tide L.

Reference to the theoretical development in § 3 shows that this tide requires special treatment.

In schedule B (i.) it appears that it must be proportional to

$$\cos^4\tfrac{1}{2}I\sqrt{1-12\tan^2\tfrac{1}{2}I\cos 2(p-\xi)}$$
$$\times\cos\left[2t+2(h-\nu)-2(s-\xi)+(s-p)-R+\pi\right] \quad . \quad (51)$$

where

$$\tan R=\frac{\sin 2\,(p-\xi)}{\frac{1}{6}\cot^2\frac{1}{2}I-\cos 2\,(p-\xi)}.$$

In this expression we must deem R to form a part of the function u, for which a mean value is to be taken. This is, it must be admitted, not very satisfactory, since p increases by nearly 41° per annum.

Suppose, then, that P be the longitude of the perigee at mid-year, measured from the intersection, and that we compute R from the formula

$$\tan R=\frac{\sin 2P}{\frac{1}{6}\cot^2\frac{1}{2}I-\cos 2P} \quad . \quad . \quad . \quad . \quad . \quad . \quad (52)$$

Then the treatment will be the same as in all the other cases, if the argument $V+u$ be taken as $2t+2(h-\nu)-2(s-\xi)+(s-p)-R+\pi$.

The factor f in this case is equal to

$$\frac{\cos^4\frac{1}{2}I}{\cos^4\frac{1}{2}\omega\cos^4\frac{1}{2}i}.\sqrt{\{1-12\tan^2\frac{1}{2}I\cos 2P\}}.$$

The Tide M_1.

Reference to schedule B (ii.) shows that this tide must be proportional to

$$e\tfrac{1}{2}\sin I\cos^2\tfrac{1}{2}I\sqrt{\{\tfrac{5}{2}+\tfrac{3}{2}\cos 2(p-\xi)\}}\times\cos[t+(h-\nu)-(s-\xi)+Q-\tfrac{1}{2}\pi]\,(52')$$

where $\tan Q=\frac{1}{2}\tan(p-\xi)$.

We must here deem Q to form a part of the function u, for which a mean value is to be taken; but as in the case of the L tide, this course is not very satisfactory.

If P as before denotes the longitude of the perigee at mid-year, measured from the intersection, and Q be computed from

$$\tan Q=\tfrac{1}{2}\tan P \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (52'')$$

then the argument $V+u$ will be

$$t+(h-\nu)-(s-\xi)+Q-\tfrac{1}{2}\pi.$$

And the factor f is

$$\frac{\sin I\cos^2\frac{1}{2}I}{\sin\omega\cos^2\frac{1}{2}\omega\cos^4\frac{1}{2}i}\sqrt{\{\tfrac{5}{2}+\tfrac{3}{2}\cos 2P\}} \quad . \quad . \quad . \quad (52''')$$

It has been shown that the tide M_1, in as far as it depends on the fourth power of the moon's parallax, is too small to be worth including in the numerical analysis.

§ 6. *On the Method of Computing the Arguments and Coefficients.*

In performing the reductions of the preceding sections a number of numerical quantities are required, which are to be derived from the position of the heavenly bodies.

Formulæ for Computing I, ν, ξ.

From Fig. 2, § 3, we see that

$$\left.\begin{aligned}\cot(N-\xi)\sin N&=\cos N\cos i+\sin i\cot\omega\\ \cot\nu\sin N&=\cos N\cos\omega+\sin\omega\cot i\\ \cos I&=\cos i\cos\omega-\sin i\sin\omega\cos N\end{aligned}\right\} \quad . \quad . \quad . \quad (53)$$

If β be an auxiliary angle defined by

$$\tan\beta=\tan i\cos N \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (54)$$

Then

$$\left.\begin{aligned}\cos I&=\cos i \sec\beta\cos(\omega+\beta)\\ \sin\nu&=\sin i \operatorname{cosec} I \sin N\\ \sin(N-\xi)&=\sin\omega \operatorname{cosec} I\sin N\end{aligned}\right\}\quad . \quad . \quad . \quad . \quad . \quad . \quad (55)$$

The formulæ (53) also lead to the rigorous formulæ

$$\left.\begin{aligned}\tan\xi&=\frac{\sin i\cot\omega\sin N(1-\tan\frac{1}{2}i\tan\omega\cos N)}{\cos^2\frac{1}{2}i+\sin i\cot\omega\cos N-\sin^2\frac{1}{2}i\cos 2N}\\ \tan\nu&=\frac{\tan i\operatorname{cosec}\omega\sin N}{1+\tan i\cot\omega\cos N}\end{aligned}\right\}\quad . \quad . \quad (53')$$

But, if we treat i as small, (53′) may be reduced to

$$\left.\begin{aligned}\tan\xi&=i\cot\omega\sin N-\tfrac{1}{2}i^2\sin 2N\frac{1-\frac{1}{2}\sin^2\omega}{\sin^2\omega}\\ \tan\nu&=i\operatorname{cosec}\omega\sin N-\tfrac{1}{2}i^2\sin 2N\frac{\cos\omega}{\sin^2\omega}\\ \cos I&=(1-\tfrac{1}{2}i^2)\cos\omega-i\sin\omega\cos N\end{aligned}\right\}\quad . \quad . \quad . \quad (53'')$$

A table of values of ξ, ν, I, for different values of N, with $\omega=23°\ 27'\cdot3$, $i=5°\ 8'\cdot8$, may be computed either directly from (53) or from (55).

We give below in § 12 a table for I, ν, ξ for every 2° of N, computed from (55) under the superintendence of Major Baird, at Poona.

The approximate formulæ (53″) will be of service hereafter.

On the Mean Values of the Coefficients in Schedules [B.].

In the three schedules [B] of lunar tides, 'the coefficients' are certain functions of I, and there are certain terms in the arguments which are functions of ν and ξ. We may typify all the terms by $J\cos(T+u)$, where J is a function of I, and u of ν and ξ. If we substitute for J and u in terms of ω, i, N, and develop the result, we shall obtain a series of terms of which the one independent of N is, say, $J_1\cos T$. Then J_1 is the mean value of the semi-range of the tide in question. Such a development may be carried out rigorously, but it involves a good deal of analysis to do so; we shall therefore confine ourselves to an approximate treatment of the question, using the formulæ (53″) for ξ and ν.

It may be proved that in no case does J involve a term with a sine of an odd multiple of N, and the formulæ (54) or (55) show that in every term of $\sin u$ there will occur a sine of an odd multiple of N; whence it follows that $J\sin u$ has mean value zero, and J_1 is the term independent of N in $J\cos u$.

It may also be proved that in no case does $\cos u$ involve a term in $\cos N$, and that the terms in $\cos 2N$ are all of order i^2; also it appears that J always involves a term in $\cos N$, and also terms in $\cos 2N$ of order i^2.

Hence to the degree of approximation adopted, J_1 is equal to $J_0\cos u_0$, where J_0 is the mean value of J, and $\cos u_0$ the mean value of $\cos u$.

In evaluating $\cos u_0$ from the formulæ (53″), we may observe that wherever $\sin^2 N$ occurs it may be replaced by $\frac{1}{2}$; for $\sin^2 N=\frac{1}{2}-\frac{1}{2}\cos 2N$, and the $\cos 2N$ has mean value zero.

The following are the values of $\cos u_\circ$ thus determined from (53′) :—

$$(\alpha)\quad \cos 2(\nu-\xi)_\circ = 1 - i^2 \left(\frac{1-\cos\omega}{\sin\omega}\right)^2$$

$$(\beta)\quad \cos 2\nu_\circ = 1 - i^2 \frac{1}{\sin^2\omega}$$

$$(\gamma)\quad \cos(2\xi-\nu)_\circ = 1 - \tfrac{1}{4}i^2\left(\frac{1-2\cos\omega}{\sin\omega}\right)^2$$

$$(\delta)\quad \cos(2\xi+\nu)_\circ = 1 - \tfrac{1}{4}i^2\left(\frac{1+2\cos\omega}{\sin\omega}\right)^2$$

$$(\epsilon)\quad \cos\nu_\circ = 1 - \tfrac{1}{4}i^2\frac{1}{\sin^2\omega}$$

$$(\zeta)\quad \cos 2\xi_\circ = 1 - i^2\cot^2\omega$$

The suffix $_\circ$ indicating the mean value.

Similarly the following are the $J_\circ$'s or mean values of J :—

$$(\alpha')\quad \cos^4\tfrac{1}{2}I_\circ = \cos^4\tfrac{1}{2}\omega\left[1+\tfrac{1}{2}i^2\frac{\sin^2\frac{1}{2}\omega-\cos\omega}{\cos^2\frac{1}{2}\omega}\right]$$

$$(\beta')\ \&\ (\zeta')\quad \sin^2 I_\circ = \sin^2\omega\left[1+i^2\frac{1-\frac{3}{2}\sin^2\omega}{\sin^2\omega}\right]$$

$$(\gamma')\quad \sin I_\circ\cos^2\tfrac{1}{2}I_\circ = \sin\omega\cos^2\tfrac{1}{2}\omega\left[1+\tfrac{1}{4}i^2\left(\frac{\cos 2\omega}{\sin^2\omega}-\frac{2\cos\omega}{\cos^2\frac{1}{2}\omega}\right)\right]$$

$$(\delta')\quad \sin I_\circ\sin^2\tfrac{1}{2}I_\circ = \sin\omega\sin^2\tfrac{1}{2}\omega\left[1+\tfrac{1}{4}i^2\left(\frac{\cos 2\omega}{\sin^2\omega}+\frac{2\cos\omega}{\sin^2\frac{1}{2}\omega}\right)\right]$$

$$(\epsilon')\quad \sin I_\circ\cos I_\circ = \sin\omega\cos\omega\left[1+\tfrac{1}{4}i^2(\cot^2\omega-5)\right]$$

On referring to schedules [B], it appears that (α) multiplied by (α') is the mean value of the $\cos^4\frac{1}{2}I\cos 2(\nu-\xi)$ which occurs in the semidiurnal terms; and so on with the other letters, two and two. Performing these multiplications, and putting $1-\frac{1}{2}i^2$ in the results as equal to $\cos^4\frac{1}{2}i$, and $1-\frac{3}{2}i^2$ as equal to $1-\frac{3}{2}\sin^2 i$, we find that the mean values are all unity for the following functions, viz. :

$$\frac{\cos^4\frac{1}{2}I\cos 2(\nu-\xi)}{\cos^4\frac{1}{2}\omega\cos^4\frac{1}{2}i},\quad \frac{\sin^2 I\cos 2\nu}{\sin^2\omega(1-\frac{3}{2}\sin^2 i)},\quad \frac{\sin I\cos^2\frac{1}{2}I\cos(2\xi-\nu)}{\sin\omega\cos^2\frac{1}{2}\omega\cos^4\frac{1}{2}i},$$

$$\frac{\sin I\sin^2\frac{1}{2}I\cos(2\xi+\nu)}{\sin\omega\sin^2\frac{1}{2}\omega\cos^4\frac{1}{2}i},\quad \frac{\sin I\cos I\cos\nu}{\sin\omega\cos\omega(1-\frac{3}{2}\sin^2 i)},\quad \frac{\sin^2 I\cos 2\xi}{\sin^2\omega\cos^4\frac{1}{2}i}.$$

Lastly, it is easy to show rigorously that the mean value of

$$\frac{1-\frac{3}{2}\sin^2 I}{(1-\frac{3}{2}\sin^2\omega)(1-\frac{3}{2}\sin^2 i)}$$

is also unity.

If we write

$$\varpi = \cos\tfrac{1}{2}\omega\cos\tfrac{1}{2}i - \sin\tfrac{1}{2}\omega\sin\tfrac{1}{2}i\,e^{N\iota}$$

$$\kappa = \sin\tfrac{1}{2}\omega\cos\tfrac{1}{2}i + \cos\tfrac{1}{2}\omega\sin\tfrac{1}{2}i\,e^{N\iota}$$

where ι stands for $\sqrt{-1}$; and let ϖ_1, κ_1 denote the same functions with the sign of N changed, then it may be proved rigorously that

$$\cos^4\tfrac{1}{2}I\cos 2(\nu-\xi) = \tfrac{1}{2}(\varpi^4+\varpi_1{}^4)$$

$$\sin^2 I\cos 2\nu = 2(\varpi^2\kappa_1{}^2+\varpi_1{}^2\kappa^2)$$

$$\sin I\cos^2\tfrac{1}{2}I\cos(2\xi-\nu) = \varpi^3\kappa+\varpi_1{}^3\kappa_1$$

$$\sin I\sin^2\tfrac{1}{2}I\cos(2\xi+\nu) = \varpi\kappa^3+\varpi_1\kappa_1{}^3$$

$$\sin I\cos I\cos\nu = (\varpi\kappa_1+\varpi_1\kappa)(\varpi\varpi_1-\kappa\kappa_1)$$

$$\sin^2 I\cos 2\xi = 2(\varpi^2\kappa^2+\varpi_1{}^2\kappa_1{}^2)$$

$$1-\tfrac{3}{2}\sin^2 I = \varpi^2\varpi_1{}^2 - 4\varpi\varpi_1\kappa\kappa_1 + \kappa^2\kappa_1{}^2$$

The proof of these formulæ, and the subsequent development of the functions of the ϖ's and κ's, constitute the rigorous proof of the formulæ, of which the approximate proof has been indicated above. The analogy between the ϖ's and κ's, and the p, q of the earlier developments of this Report, is that if i vanishes $\varpi=\varpi_1=p$, $\kappa=\kappa_1=q$.

[See a paper in the *Phil. Trans. R.S.* Part II. 1880, p. 713.]

This investigation justifies the statements preceding the schedules [B] as to the mean values of the coefficients.

Formulæ for computing f.

In the original reduction of tidal observations we want 1/f; in the use of the tide-predicter f is required.

On looking through the schedules [B.], we see that the following values of 1/f are required.

$$(1)\ \frac{\cos^4\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\cos^4\frac{1}{2}I},\quad (2)\ \frac{\sin^2\omega\,(1-\frac{3}{2}\sin^2 i)}{\sin^2 I},\quad (3)\ \frac{\sin\omega\cos^2\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\sin I\cos^2\frac{1}{2}I},$$

$$(4)\ \frac{\sin\omega\sin^2\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\sin I\sin^2\frac{1}{2}I},\quad (5)\ \frac{\sin\omega\cos\omega\,(1-\frac{3}{2}\sin^2 i)}{\sin I\cos I},$$

$$(6)\ \frac{\sin^2\omega\cos^4\frac{1}{2}i}{\sin^2 I},\quad (7)\ \frac{(1-\frac{3}{2}\sin^2\omega)(1-\frac{3}{2}\sin^2 i)}{(1-\frac{3}{2}\sin^2 I)}.$$

And in the case of the over-tides and compound tides (schedules [F], [H]), powers and products of these quantities.

A table of values of these functions for various values of I is given in § 12.

The functions (2) and (5) are required for computing f for the K_1 and K_2 tides.

In this list of functions let us call that numbered (2) k_2, and that numbered (5) k_1; k_2 and k_1 being the values of the reciprocal of f which would have to be applied in the cases of the K_2 and K_1 tides, if the sun did not exist.

On referring back to the paragraph in § 5 in which the treatment of the K_2 and K_1 tides is explained we see that for K_2

$$\frac{S}{M} = \cdot 46407 \times k_2,$$

and therefore from (44) we see that for K_2

$$\left.\begin{aligned} \frac{1}{f} &= \frac{1 \cdot 46407}{\{1+(0 \cdot 46407 \times k_2)^2 + 0 \cdot 92814 k_2 \cos 2\nu\}^{\frac{1}{2}}} \\ \tan 2\nu'' &= \frac{\sin 2\nu}{\cos 2\nu + \cdot 46407\, k_2} \end{aligned}\right\} \quad . \quad . \quad (56)$$

And for K_1 the similar formulæ hold with k_1 in place of k_2, and ν in place of 2ν.[1]

Tables of $1/f$ and ν', $2\nu''$ for the K_1 and K_2 tides may be formed from (56).

The angle I ranges from $18° \; 18' \cdot 5$, when it is $\omega - i$, to $28° \; 36' \cdot 1$, when it is $\omega + i$.

Then for any value of N we first extract I, and afterwards find the coefficients from the subsequent tables.

The coefficients for the over-tides and compound tides may be found from tables of squares and cubes and by multiplication.

Formulæ for s, p, h, p_1, N.

The numerical values may be deduced from the formulæ given in Hansen's *Tables de la Lune*. The following are reduced to a more convenient epoch, and to forms appropriate to the present investigation.

$$\left.\begin{aligned} s &= 150° \cdot 0419 + [13 \times 360° + 132° \cdot 67900]\, T + 13° \cdot 1764\, D \\ &\qquad\qquad + 0° \cdot 5490165\, H \\ p &= 240° \cdot 6322 + 40° \cdot 69035\, T + 0° \cdot 1114\, D + 0° \cdot 0046418\, H \\ h &= 280° \cdot 5287 + 360° \cdot 00769\, T + 0° \cdot 9856\, D + 0° \cdot 0410686\, H \\ p_1 &= 280° \cdot 8748 + 0° \cdot 01711\, T + 0° \cdot 000047\, D \\ N &= 285° \cdot 9569 - 19° \cdot 34146\, T - 0° \cdot 0529540\, D \end{aligned}\right\} \quad . \quad . \quad (57)$$

Where

T is the number of Julian years of $365\frac{1}{4}$ mean solar days,

D the number of mean solar days,

H the number of mean solar hours,

after 0^h Greenwich mean time, January 1, 1880.

From the coefficients of H we see that

$$\sigma = 0° \cdot 5490165, \quad \varpi = 0° \cdot 0046418, \quad \eta = 0° \cdot 0410686 \quad . \quad . \quad (58)$$

whence $\gamma = 15° \cdot 0410686$.

[1] This method of treating these tides is due to Professor Adams. I had proposed to divide the K tides into their lunar and solar parts.—G.H.D.

For the purposes of using the forms for harmonic analysis of the tidal observations, these formulæ may be reduced to more convenient and simpler forms.

The mean values of N and p_1 are required, and for the treatment of the L and M_1 tides the mean value of $p-\xi$, denoted by P. For determining these three quantities, we may therefore add half the coefficient of T once for all, and write

$$\left.\begin{aligned} N&=276°\cdot2861-0°\cdot05295\,D-19°\cdot34146\,T\\ p_1&=280°\cdot8833+0°\cdot00005\,D+\ \ 0°\cdot01711\,T\\ P+\xi&=261°\cdot0\quad\ +0°\cdot111\,D\quad +40°\cdot69\,T \end{aligned}\right\}\quad . \quad . \quad . \quad . \quad (59)$$

where T is simply the number of years, whether there be leap-years or not amongst them, since 1880, and D the number of days from Jan. 1, numbered as zero up to the first day of the year to be analysed.

Now, suppose d to denote the number of quarter days either one, two, or three in excess of the Julian years which have elapsed since 0^h Jan. 1, 1880, up to 0^h Jan. 1 of the year in question; let D denote the same as before; and let L be the East Longitude of the place of observation in hours and decimals of hours.

Then for s_o, p_o, h_o, the values of s, p, h at 0^h of the first day, we have

$$\left.\begin{aligned} s_o&=150°\cdot0419+132°\cdot67900\,T+3°\cdot29410\,d+13°\cdot1764\,D-0°\cdot54902\,L\\ p_o&=240°\cdot6322+\ \ 40°\cdot69035\,T+0°\cdot02785\,d+\ \ 0°\cdot1114\,D-0°\cdot00464\,L\\ h_o&=280°\cdot5287+\quad 0°\cdot00769\,T+0°\cdot24641\,d+\ \ 0°\cdot9856\,D-0°\cdot04107\,L \end{aligned}\right\}(60)$$

In these formulæ T is an integer, being the excess of the year in question above 1880, and d is to be determined thus:—if the excess of the year above 1880 divided by 4 leaves remainder 3, d is 1; if remainder 2, it is 2; if remainder 1, it is 3; and if remainder zero, it is zero. For example for 1895, $T=15$, $d=1$; because from 0^h Jan. 1, 1880 to 0^h Jan. 1, 1895, is 15 Julian years and a quarter day. For all dates after Feb. 28, 1900, one day's motion must be subtracted from s_o, p_o, h_o, p_1, $P+\xi$, and one day's motion added to N.

The terms in L may be described as corrections for longitude.

The $13\times360°$ and $360°$ which occurred in the previous formulæ for s and h are now omitted, because T is essentially an integer.

If it be preferred, the values of s_o and N may be extracted from the *Nautical Almanac*, and h_o is (neglecting nutation) the sidereal time reduced to angle. We may take p_o from a formula given by Hansen at p. 300 of the *Tables de la Lune*. This latter course is that which is followed in the forms for computation.

§ 7. *Summary of Initial Arguments and Factors of Reduction.*

The results for the various kinds of tide are scattered in various parts of the above, and it will therefore be convenient to collect them together. In order to present the results in a form convenient for computation, each argument is given by reference to any previous argument which contains the same element. In the following schedule Arg. M_2 and Fac. M_2 (for example) mean the argument and factor computed for the tide M_2.

[I.]

Schedule of Arguments at 0^h *of the first day, and Factors for Ensuing Year.*

	Initial Arguments. $V_\circ + u$	Factors for Reduction. $\frac{1}{f}$
S_1 S_2 S_3 S_4	zero	unity
P	$-h_\circ + \frac{1}{2}\pi$	unity
T	$-(h_\circ - p_1)$	unity
M_1	$(h_\circ - \nu) - (s_\circ - \xi) + Q - \frac{1}{2}\pi$ where $\tan Q = \frac{1}{2} \tan P$	Fac. O $\div \sqrt{\{\frac{5}{2} + \frac{3}{2}\cos 2P\}}$
M_2	$2(h_\circ - \nu) - 2(s_\circ - \xi)$	$\left(\frac{\cos \frac{1}{2}\omega \cos \frac{1}{2}i}{\cos \frac{1}{2}I}\right)^4$
M_3	$\frac{3}{2}$ Arg. M_2	(Fac. $M_2)^{\frac{3}{2}}$
M_4	2 Arg. M_2	(Fac. $M_2)^2$
M_6	3 Arg. M_2	(Fac. $M_2)^3$
M_8	4 Arg. M_2	(Fac. $M_2)^4$
K_2	$2h_\circ - 2\nu''$ where $\tan 2\nu'' = \frac{\sin 2\nu}{\cos 2\nu + \cdot 464 \times k}$	$\frac{1 \cdot 46407}{\sqrt{\{1 + (\cdot 464 \times k)^2 + \cdot 928 k \cos 2\nu\}}}$ where $k = \frac{\sin^2 \omega\,(1 - \frac{3}{2}\sin^2 i)}{\sin^2 I}$
K_1	$h_\circ - \nu' - \frac{1}{2}\pi$ where $\tan \nu' = \frac{\sin \nu}{\cos \nu + \cdot 464 \times k}$	$\frac{1 \cdot 46407}{\sqrt{\{1 + (\cdot 464 \times k)^2 + \cdot 928\, k \cos \nu\}}}$ where $k = \frac{\sin 2\omega (1 - \frac{3}{2}\sin^2 i)}{\sin 2I}$
N	Arg. $M_2 - (s_\circ - p_\circ)$	Fac. M_2
2N	Arg. $N - (s_\circ - p_\circ)$	Fac. M_2
L	Arg. $M_2 + (s_\circ - p_\circ) - R + \pi$ where $\tan R = \frac{\sin 2P}{\frac{1}{6}\cot^2 \frac{1}{2}I - \cos 2P}$	Fac. $M_2 \div \sqrt{1 - 12 \tan^2 \frac{1}{2}I \cos 2P}$
ν	Arg. $M_2 + (s_\circ - p_\circ) + 2h_\circ - 2s_\circ$	Fac. M_2

	Initial Arguments. $V_\circ + u$	Factors for Reduction. $\frac{1}{f}$
O	$(h_\circ - \nu) - 2(s_\circ - \xi) + \frac{1}{2}\pi$	$\dfrac{\sin\omega\cos^2\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\sin I\cos^2\frac{1}{2}I}$
OO	$(h_\circ - \nu) + 2(s_\circ - \xi) - \frac{1}{2}\pi$	$\dfrac{\sin\omega\sin^2\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\sin I\sin^2\frac{1}{2}I}$
Q	Arg. O $-(s_\circ - p_\circ)$	Fac. O
J	$(h_\circ - \nu) + (s_\circ - p_\circ) - \frac{1}{2}\pi$	$\dfrac{\sin 2\omega(1-\frac{3}{2}\sin^2 i)}{\sin 2I}$
MS	Arg. M_2	Fac. M_2
2MS	Arg. M_4	Fac. M_4
2SM	2π—Arg. M_2	Fac. M_2
MK	Arg. M_2 + Arg. K_1	Fac. $M_2 \times$ Fac. K_1
2MK	Arg. M_4 − Arg. K_1	Fac. $M_4 \times$ Fac. K_1
MN	Arg. M_2 + Arg. N	Fac. $M_2 \times$ Fac. N
MSf	2π—Arg. M_2	Fac. M_2
Mm	$(s_\circ - p_\circ)$	$\dfrac{(1-\frac{3}{2}\sin^2\omega)(1-\frac{3}{2}\sin^2 i)}{1-\frac{3}{2}\sin^2 I}$,
Mf	$2(s_\circ - \xi)$	$\dfrac{\sin^2\omega\cos^4\frac{1}{2}i}{\sin^2 I}$
Sa	$h_\circ$	unity
Ssa	$2h_\circ$	unity

There are two tables, numbered I. and II., given at pp. 304 and 305 of the Report for 1876 of the Committee of the British Association on Tidal Observations. The columns headed ϵ give functions which, when their signs are reversed, are the arguments at the epoch. To show the identity of these expressions with those in the above schedule [I], we must put

$$f = -h_\circ,\quad g = -h_\circ,\quad ☽ = s_\circ + \nu - \xi,\quad \odot = h_\circ,\quad \varpi' = p_\circ + \nu - \xi,\quad \varpi = p_1.$$

For the sake of symmetry these tables contain several entries which

we have omitted from our schedule, because of the smallness of the tides to which they refer. The entries of the tides of long period, Nos. 3 and 4, are given with the opposite sign from that here adopted;[1] thus those entries require alteration by 180° to bring them into accordance with our schedule.

The following corrections have to be made in Table II.: No. 8, for 2ν read 3ν; No. 15, add 4ν; Nos. 17 and 19, add $2(\nu-\xi)$; Nos. 18 and 20, subtract $2(\nu-\xi)$.

The K_1, K_2 tides, Nos. 9 and 16 of both tables, are entered separately as to their lunar and solar parts. The two parts of the M_1 tide, Nos. 7 and 11, are entered separately. Also No. 14 only gives one part of the tide here entered as L.

The reader is warned that the definition of ϵ on p. 293 is incomplete, and incorrect for proper reference to the equilibrium theory of tides. The definition of ϖ' on p. 302 is incorrect.

§ 8. *On the Reductions of the Published Results of Tidal Analysis.*

In the Tide Tables published by the Indian Government, it is stated that each tide is expressed in the form R cos $(nt-\epsilon)$, where R is the semi-range in feet, n the speed of the tide, and ϵ/n is the time in mean solar hours which elapses, after an epoch appropriate to the tide, until the next high-water of that tide. Tables are then given for R and ϵ at each station for each year.

The mode of tabulation is the same as that followed in the Tidal Reports of the British Association for 1872 and 1876.

It is advisable that all the results should be reduced according to one system, such that the observations of the several years and the values for the several speeds of tide may be comparable *inter se*.

In § 5 it has been proposed that the tide should be recorded in the form

$$\mathrm{fH}\cos(V+u-\kappa).$$

It appears from the statements in the Reports for 1872 and 1876 and from an examination of the reductions of the published results that the ϵ of the tables is equal to $\kappa-u$, and that the R of the tables is equal to fH. Thus in order to reduce the published results to proper forms, comparable *inter se*, it is necessary to add to ϵ the appropriate u, and to divide R by the proper f. Following this process we obtain at once the following *additive* corrections to the ϵ's to obtain the κ's. The values of $1/\mathrm{f}$ by which the R's are to be multiplied to obtain the H's, are those given in the preceding schedule [I].

For all tides not mentioned here, κ is identical with ϵ, and H with R.

[1] See the passage in §2 between equations (28) and (29).

[J.]

Schedule for Reducing Published Results.

Tide	Correction to ϵ to find κ	Tides	Correction to ϵ to find κ
M_2, N, ν	$-2(\nu-\xi)$	O, Q	$-\nu+2\xi+\frac{1}{2}\pi$
M_1	$-(\nu-\xi)+Q-\frac{1}{2}\pi$	J	$-\nu-\frac{1}{2}\pi$
M_3	$-3(\nu-\xi)$	P	$+\frac{1}{2}\pi$
M_4	$-4(\nu-\xi)$	T	$+p_1$
M_6	$-6(\nu-\xi)$	R	$-p_1+\pi$
M_8	$-8(\nu-\xi)$	MS	$-2(\nu-\xi)$
K_2	$-2\nu''$	2MS or μ	$-4(\nu-\xi)$
K_1	$-\nu'-\frac{1}{2}\pi$	2SM	$+2(\nu-\xi)$
L	$-2(\nu-\xi)-R+\pi$	Fortnightly	-2ξ
λ	$-2(\nu-\xi)+\pi$	Synodic Fortnightly	$+2(\nu-\xi)$

In a paper by Captain Evans and Sir William Thomson, read before the British Association in 1878, certain tidal results are given which require a slightly different treatment in order to reduce them to the system now in view. It appears that for these results, schedule [J] is applicable if we erase all the $\frac{1}{2}\pi$'s and π's that occur therein, except in the single case of the tide M_1.

§ 9. *Description of the Numerical Harmonic Analysis for the Tides of Short Period.*

It forms no part of the plan of this Report to give an account of the instruments with which the tidal observations are made, or of the tide-predicting instrument. A description of the tide-gauge, which is now in general use in India and elsewhere, and of the tide-predicter, which is at the India Store Department in Lambeth, and of designs for modifications of those instruments, has been given in a paper by Sir William Thomson, read before the Institution of Civil Engineers on March 1, 1881,[1] and to this paper we refer the reader. Our present object is to place on record the manner in which the observations have been or are to be

[1] 'The Tide Gauge, Tidal Harmonic Analyser, and Tide Predicter,' *Proc. Inst. C.E.* vol. 45, part iii.

henceforth treated, and to give the requisite information for the subsequent use of the tide-predicting instrument.

The tide-gauge furnishes us with a continuous graphical record of the height of the water above some known datum mark for every instant of time.

It is probable that at some future time the Harmonic Analyser of Professors James and Sir William Thomson [1] may be applied to the tide-curves. The instrument is nearly completed, and now lies in the Physical Laboratory of the University of Glasgow, but it has not yet been put into use. The treatment of the observations which we shall describe is the numerical process used at the office of the Indian Survey at Poona, under the immediate superintendence of Major A. W. Baird, R.E. The printed forms for computation were admirably drawn up by Mr. Edward Roberts, of the 'Nautical Almanac' Office; but they have now undergone certain small modifications in accordance with this Report. The work of computation is to a great extent carried out by native Indian computers. The results of the harmonic analysis are afterwards sent to Mr. Roberts, who works out the instrumental tide-predictions for the several ports for the ensuing year. The use of that instrument requires great skill and care. The results of the tidal reductions have hitherto been presented in a somewhat chaotic form, and we believe that it is only due to Mr. Roberts' knowledge of the manner in which the tidal results have been treated that they have been correctly used for prediction. It may be hoped that the use of the methods recommended in the present Report will remove some of the factitious difficulties in the use of the instrument.

The first operation performed on the tidal record is the measurement in feet and decimals of the height of water above the datum at every mean solar hour. The period chosen for analysis is about one year, and the first measurement corresponds to noon. It has been found impracticable to make the initial noon belong to the same day at the several ports. It would seem, at first sight, preferable to take the measurements at every mean lunar hour; but the whole of the actual process in use is based on measurements taken at the mean solar hours, and a change to lunar time would involve a great deal of fresh labour and expense.

If T be the period of any one of the diurnal tides, or the double period of any one of the semi-diurnal tides, it approximates more or less nearly to 24 m. s. hours, and if we divide it into 24 equal parts, we may speak of each as a T-hour. We shall for brevity refer to mean solar time as S-time.

Suppose, now, that we have two clocks, each marked with 360°, or 24 hours, and that the hand of the first, or S-clock, goes round once in 24 S-hours, and that of the second, or T-clock, goes round once in 24 T-hours, and suppose that the two clocks are started at 0° or 0^h at noon of the initial day. For the sake of distinctness, let us imagine that a T-hour is longer than an S-hour, so that the T-clock goes slower than the S-clock. The measurements of the tide-curve give us the height of water exactly at each S-hour; and it is required from these data to determine the height of water at each T-hour.

For this end we are, in fact, instructed to count T-time, but are only allowed to do so by reference to S-time, and, moreover, the time is always to be specified as an integral number of hours.

[1] See Appendix, Thomson and Tait's *Nat. Phil.* 2nd ed. 1883.

Beginning, then, with 0^h of the first day, we shall begin counting 0, 1, 2, &c., as the T-hand comes up to its hour-marks. But as the S-hand gains on the T-hand, there will come a time when the T-hand, being exactly at the p hour-mark, the S-hand is nearly as far as $p+\frac{1}{2}$. When, however, the T-hand has advanced to the $p+1$ hour-mark, the S-hand will be a little beyond $p+1+\frac{1}{2}$: that is to say, a little less than half an hour before $p+2$. Counting, then, in T-time by reference to S-time, we shall jump from p to $p+2$. The counting will go on continuously for a number of hours nearly equal to $2p$, and then another number will be dropped, and so on throughout the whole year. If it had been the T-hand which went faster than the S-hand, it is obvious that one number would be repeated at two successive hours instead of one being dropped. We may describe each such process as a 'change.'

Now, if we have a sheet marked for entry of heights of water according to T-hours from results measured at S-hours, we must enter the S-measurements continuously up to p, and we then come to a 'change,' and dropping one of the S-series, we go on again continuously until another 'change,' when another is dropped, and so on.

Since a 'change' occurs at the time when a T-hour falls almost exactly half way between two S-hours, it will be more accurate at a 'change' to insert the two S-entries which fall on each side of the truth. If this be done the whole of the S-series of measurements is entered on the T-sheet. Similarly, if it be the T-hand which goes faster than the S-hand, we may leave a gap in the T-series instead of duplicating an entry. For the analysis of the T-tide there is therefore prepared a sheet arranged in rows and columns; each row corresponds to one T-day, and the columns are marked 0^h, 1^h, . . . 23^h; the 0^h's may be called T-noons. A dot is put in each space for entry, and where there is a change two dots are put if there is to be a double entry, and a bar if there is to be no entry. Black vertical lines mark the end of each S-day. These black lines will of course fall into slightly irregular diagonal lines across the page, and such lines are steeper and steeper the more nearly T-time approaches to S-time. They slope downwards from right to left if the T-hour is longer than the S-hour, and the other way in the opposite case. The 'changes' also run diagonally, with a slope in the opposite direction to that of the black lines.

We annex a diminished sample of a part of a page drawn up for the entry of the M-series of tides, in which T-time is mean lunar time.

Schedule [K].—*Form for Entry of Tidal Observations.*

SERIES M.

	0^h	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	12^h	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	*S*-hour
1															:										2^d 0^h
2																			:						3 1
3																								:	4 2
4																									5 2
5				:																					6 3
&c.													&c.								&c.				
67																									70 7
68				:																					71 8
69									:																72 9
70														:											73 10
71																		:							74 11
Sum																									
No.	73	73	74	74	73	73	73	73	75	73	73	73	74	74	74	73	73	75	74	73	73	74	73	74	No. of Days 73^d 12^h

In the form actually prepared for the computers, the horizontal lines between the successive days are absent, and the place for each single entry is indicated by a single dot.

The incidence of the hours in the computation forms for the several series was determined by Mr. Roberts.

Since the first day is numbered 1, and the first hour 0^h, it follows that the hourly observation numbered $74^d\ 11^h$ is the observation which completes a period of $73^d\ 12^h$ of mean solar time since the beginning; in fact, to find the period elapsed since 0^h of the first day we must subtract 1 from the number of the day and add one to the number of the hour. The $73^d\ 12^h$ of m. s. time, inserted at the foot of the form, is very nearly equal to 71 days of mean lunar or M-time. For each class of tide there are five pages, giving in all about 370 values for the height of the water at each of the 24 special hours; the number of values for each hour varies slightly according as more or less 'changes' fall into each column.

The numbers entered in each column are summed on each of the five pages; the five sets of results being summed, the results are then divided each by the proper divisor for its column, and thus is obtained the mean value for that column. In this way 24 numbers are found which give the mean height of water at each of the 24 special hours.

It is obvious that if this process were continued over a very long time we should in the end extract the tide under analysis from amongst all the others, but as the process only extends over about a year, the elimination of the others is not quite complete.

The elimination of the effects of the other tides may be improved by choosing the period for analysis not exactly equal to one year. For suppose that the expression for the height of water is

$$A_1 \cos n_1t + B_1 \sin n_1t + A_2 \cos n_2t + B_2 \sin n_2t \quad . \quad . \quad . \quad (61)$$

where n_2 is nearly equal to n_1, and that we wish to eliminate the n_2-tide, so as to be left only with the n_1-tide.

Now, this expression is equal to

$$\left.\begin{aligned} &\{A_1 + A_2 \cos (n_1-n_2)t - B_2 \sin (n_1-n_2)t\} \cos n_1t \\ +&\{B_1 + A_2 \sin (n_1-n_2)t + B_2 \cos (n_1-n_2)t\} \sin n_1t \end{aligned}\right\} \quad . \quad . \quad (62)$$

That is to say, we may regard the tide as oscillating with a speed n_1, but with slowly-varying range. Now we want to find the mean semi-ranges A_1, B_1 of such an oscillation, and these will be found if we take the average semi-ranges estimated over a good many periods $2\pi/(n_1-n_2)$. It will be best to stop exactly at the termination of such a period, so that the number of positive errors may be as nearly as possible equal to the number of negative ones.

It is of course impossible to choose for each tide n_1 a period which shall minimise the effects of more than one of the tides of short period n_2 in vitiating the values of mean semi-ranges of the tide n_1, and accordingly the periods have been chosen so as to minimise the effect of the principal solar semi-diurnal tide S_2 upon the principal lunar semi-diurnal tide M_2, and of the M_2-tide upon the others.

If n_1 be a diurnal tide and n_2 a semi-diurnal one, it does not seem worth while to choose any particular period for the averaging process, because the coefficients will go through so large a number of oscillations (about 350) in the course of the year. Nevertheless, special periods for

the evaluation of the diurnal tides have been chosen, and the reason for the choice, alleged in the Report to the British Association for 1872, seems to be to minimise the effect of the M_2-tide on the diurnal tide. The period intended to be chosen (for the arithmetic seems to have been incorrectly worked out) will, it is true, minimise the effect of the M_1-tide; the M_1-tide is, however, so small that it appears to the writer that there was no advantage gained by the choice.

The computation forms show the following periods.

[L.]

Periods over which the Harmonic Analysis extends in the several series of Tides of Short Period.

Tide	Period in S days d h	Period in special days d h
S	369 3	369 3
M	369 3	356 15
O	369 3	343 3
K	369 3	370 3
P	369 3	368 3
J	370 5	384 16
Q	370 5	330 17
L	369 3 or 358 6	363 8 or 352 15
N	369 3 or 358 6	349 22 or 339 15
λ	349 22 or 369 3	343 14 or 362 10
ν	349 22 or 369 3	332 14 or 350 20
μ or 2MS	369 3	344 3
R	369 3	369 15
T	369 3	368 15
MS	369 3	362 21
2SM	369 3	381 15

The computation forms for the L, N, λ, ν tides have been drawn up in alternative forms, so that the computer may stop at the shorter period if desirable.

It is proposed to drop the reduction of the tides λ and R, and to add certain new tides which have been denoted 2N, MK, 2MK. These last have been made to extend over a period of $369^d\ 3^h$. This period was chosen because if we put $n_1=2(\gamma-\sigma)$, $n_2=2(\gamma-\eta)$, we have $n_2-n_1=2(\sigma-\eta)$; and $369^d\ 3^h\ 11^m$ is equal to 25 periods of an angular velocity $2(\sigma-\eta)$.

Again, if we put $n_1=2\gamma-3\sigma+\varpi$ or $2\gamma-\sigma-\varpi$, and $n_2=2(\gamma-\sigma)$ we have n_2-n_1, or n_1-n_2 equal to $\sigma-\varpi$; and $358^d\ 5^h\ 1^m$ is equal to 13 periods of an angular velocity $\sigma-\varpi$. The $358^d\ 6^h$ which occurs in the computation forms is a mistake for $358^d\ 5^h$.

Next, if we put $n_1=2\gamma-3\sigma-\varpi+2\eta$ or $2\gamma-\sigma+\varpi-2\eta$, and $n_2=2(\gamma-\sigma)$ we have n_2-n_1, or n_1-n_2 equal to $2(\sigma-\eta)-(\sigma-\varpi)$; and $349^d\ 22^h\ 21^m$ is equal to 11 periods of an angular velocity $\sigma+\varpi-2\eta$.

Lastly, if we put $n_1=\gamma-3\sigma+\varpi$ or $\gamma+\sigma-\varpi$, and $n_2=\gamma-\sigma$ we have n_2-n_1 or n_1-n_2 equal to $2\sigma-\varpi$; and $370^d\ 9^h\ 46^m$ is equal to 27 periods of an angular velocity $2\sigma-\varpi$. The $370^d\ 5^h$ which occurs in the computation forms is a mistake for $370^d\ 10^h$.

We may here remark that there does not seem to be any advantage in the choice of 369^{d} 3^{h} as the period, excepting in the analysis for the M-series and S-series. At the same time there is no harm in that choice, and therefore the computation forms may be used as they exist. The choice of a special period for the diurnal tides J and Q also appears to be useless, and therefore they may be safely used for the period of 370^{d} 5^{h} based on erroneous arithmetic. It may perhaps be worth while to cut off the last entry in the L and N forms, and thus bring the pericd to its correct value.

Let us now return to our general notation, and consider the 24 mean values, each pertaining to the 24 T-hours. We suppose that all the tides excepting the T-tide are adequately eliminated, and, in fact, a computation of the necessary corrections for the absence of complete elimination, which is given in the Tidal Report of 1872, shows that this is the case.

It is obvious that any one of the 24 values does not give the true height of the T-tide at that T-hour, but gives the average height of the water, as due to the T-tide, estimated over half a T-hour before and half a T-hour after that hour. We must now consider the correction necessary on this account.

Suppose we have a function

$$h=A_1\cos\theta+B_1\sin\theta+A_2\cos 2\theta+B_2\sin 2\theta+\ldots\\ +A_r\cos r\theta+B_r\sin r\theta+\ldots.$$

Then we see by integration that the function

$$h'=A_1'\cos\theta+B_1'\sin\theta+A_2'\cos 2\theta+B_2'\sin 2\theta+\ldots\\ +A_r'\cos r\theta+B_r'\sin r\theta+\ldots,$$

where

$$\frac{A_1'}{A_1}=\frac{B_1'}{B_1}=\frac{\sin\frac{1}{2}\alpha}{\frac{1}{2}\alpha};\ \frac{A_2'}{A_2}=\frac{B_2'}{B_2}=\frac{\sin\frac{1}{2}2\alpha}{\frac{1}{2}2\alpha};\ \ldots\ \frac{A_r'}{A_r}=\frac{B_r'}{B_r}=\frac{\sin\frac{1}{2}r\alpha}{\frac{1}{2}r\alpha};\ \ldots,$$

is derivable from h by substituting for the h, corresponding to any value of θ, the mean value of h estimated over the interval from $\theta+\frac{1}{2}\alpha$ to $\theta-\frac{1}{2}\alpha$.

Thus when harmonic analysis is applied to the 24 T-hourly values, the coefficients which express that oscillation which goes through its period r times in the 24 T-hours must be augmented by the factor $\frac{1}{2}r\alpha/\sin\frac{1}{2}r\alpha$. Thus we get the following expressions for the augmenting factors for the diurnal, semi-diurnal, ter-diurnal oscillations, &c., viz.:—

$$\frac{7\cdot 5\pi}{180}\Big/\sin 7^\circ 30';\ \frac{15\pi}{180}\Big/\sin 15^\circ;\ \frac{22\cdot 5\pi}{180}\Big/\sin 22^\circ 30', \text{ \&c.} \quad . \quad (63)$$

Computing from these we find the following augmenting factors.

[M.]

Augmenting Factors.

For A_1, B_1 . . .	1·00286
A_2, B_2 . . .	1·01152
A_3, B_3 . . .	1·02617
A_4, B_4 . . .	1·04720
A_6, B_6 . . .	1·11072
A_8, B_8 . . .	1·20920

In the reduction of the S-series of tides, the numbers treated are the actual heights of the water exactly at the *S*-hours, and therefore no augmenting factor is requisite.

We must now explain how the harmonic analysis, which the use of these factors presupposes, is carried out.

If t denotes *T*-time expressed in hours, and n is 15°, we express the height h, as given by the averaging process above explained, by the formula

$$h=A_0+A_1 \cos nt+B_1 \sin nt+A_2 \cos 2nt+B_2 \sin 2nt+ \ldots .$$

where t is 0, 1, 2 .... 23.

Then if Σ denotes summation of the series of 24 terms found by attributing to t its 24 values, it is obvious that

$$A_0=\tfrac{1}{24}\Sigma h;\ A_1=\tfrac{1}{12}\Sigma h \cos nt;\ B_1=\tfrac{1}{12}\Sigma h \sin nt;$$
$$A_2=\tfrac{1}{12}\Sigma h \cos 2nt;\ B_2=\tfrac{1}{12}\Sigma h \sin 2nt;\ \&c., \&c.$$

Since n is 15° and t is an integer, it follows that all the cosines and sines involved in these series are equal to one of the following: viz. 0, $\pm \sin 15°$, $\pm \sin 30°$, $\pm \sin 45°$, $\pm \sin 60°$, $\pm \sin 75°$, ± 1. It is found convenient to denote these sines, as 0, $\pm S_1$, $\pm S_2$, $\pm S_3$, $\pm S_4$, $\pm S_5$, ± 1. The multiplication of the 24 h's by the various S's, and the subsequent additions may be arranged in a very neat tabular form.

We append the form for the reduction of the M-tides, filled in for Karachi 1880–81, but abridged by the omission of some of the decimals. The columns marked M are the multipliers appropriate for each series.

The columns I. and II. contain the 24 hourly values to be submitted to analysis. The subsequent operations are sufficiently indicated by the headings to the columns, and it will be found on examination that the results are in reality the sums of the several series indicated above. We believe that this mode of arranging the harmonic analysis is due to Archibald Smith, who gives it in the Admiralty manual on the Compass. The arrangement seems to be very nearly the same as that adopted by Everett (*Trans. Roy. Soc. Edinb.* 1860) in his reductions of observations on underground temperature.

In most cases it is not necessary to deduce more than the tide of the speed indicated by astronomical theory, but we give the full form by which the over-tides are deducible. If we want only a diurnal tide, then the only columns necessary are I. to VII. and IX. and X.; if only a semidiurnal tide, the columns to be retained are I., II., III., XII., XIII., XV., XVI., XVII.

[N.]

Abridged Copy of Harmonic Analysis for M-Series, Karachi 1880-81.

I.		II.		III. I.+II.	IV. I.−II.	V. Lower half of IV. reversed	VI. IV.+V.	M	VII. M×VI.	M	VIII. M×VII.	IX. IV.−V.	M	X.	M	XI. M×IX.
h 0	7·1	h 12	6·9	14·0	+·19	. . .	+·19	0	·00	0	·00	+·19	1	+ ·19	1	+ ·19
1	8·3	13	8·1	16·4	+·20	−·14	+·05	S_1	+ ·01	S_3	+ ·04	+·34	S_5	+ ·33	S_3	+ ·24
2	9·3	14	9·1	18·4	+·16	−·09	+·08	S_2	+ ·04	1	+ ·08	+·25	S_4	+ ·22	0	+ ·00
3	9·8	15	9·7	19·5	+·09	−·02	+·07	S_3	+ ·05	S_3	+ ·05	+·11	S_3	+ ·08	$-S_3$	− ·08
4	9·6	16	9·6	19·3	+·01	+·04	+·06	S_4	+ ·05	0	·00	−·03	S_2	− ·01	−1	+ ·03
5	8·8	17	8·8	17·6	−·02	+·03	+·01	S_5	+ ·01	$-S_3$	− ·01	−·05	S_1	− ·01	$-S_3$	+ ·04
6	7·6	18	7·6	15·1	−·02	. . .	−·02	1	− ·02	−1	+ ·02	−·02	0	− ·00	0	+ ·00
7	6·3	19	6·3	12·6	+·03											
8	5·3	20	5·3	10·6	+·04			12	+ ·14	12	+ ·18		12	+ ·78	12	+ ·42
9	4·7	21	4·7	9·5	−·02			$B_1=$	+·012	$B_3=$	+·015		$A_1=$	+·065	$A_3=$	+·035
10	4·9	22	5·0	9·8	−·09											
11	5·7	23	5·9	11·6	−·14											

XII. First half of III.	XIII. Second half of III.	XIV. XII.+XIII.	XV. XII.−XIII.	M	XVI. M × XV.	M	XVII. M × XV.	M	XVIII. M × XV.	M	XIX. M × XV.
14·0	15·1	29·1	− 1·1	0	·00	1	−1·1	0	·0	1	−1·1
16·4	12·6	29·0	+ 3·8	S_2	+ 1·9	S_4	+3·3	1	+ 3·8	0	·0
18·4	10·6	29·0	+ 7·8	S_1	+ 6·8	S_2	+3·9	0	·0	−1	−7·8
19·5	9·5	29·0	+10·0	1	+10·0	0	0	−1	−10·0	0	·0
19·3	9·8	29·1	+ 9·4	S_4	+ 8·2	$-S_2$	−4·7	0	·0	1	+9·4
17·6	11·6	29·2	+ 6·0	S_2	+ 3·0	$-S_4$	−5·2	1	+ 6·0	0	·0
				12	+29·8	12	−3·8	12	− ·2	12	+ ·5
				$B_2=$	+ 2·49	$A_2=$	− ·32	$B_6=$	− ·02	$A_6=$	+ ·04

XX. First half of XIV.	XXI. Sec. half of XIV.	XXII. XX.−XXI.	M	XXIII. M × XXII.	M	XXIV. M × XXII.	XXV. XX.+XXI.	M	XXVI. M × XXV.	M	XXVII. M × XXV.	Values of Multipliers (M).
												$0=0$
29·2	29·0	+·18	0	·00	1	+·18	58·1	0	0	1	+58·1	$S_1=$ ·25882
29 0	29·1	−·03	S_1	−·02	S_2	−·01	58·1	S_1	+50·3	$-S_2$	−29 1	$S_2=$ ·50000
29·0	29·2	−·16	S_4	−·14	$-S_2$	+·03	58·1	$-S_4$	−50 4	$-S_2$	−29·1	$S_3=$ ·70711
			12	−·17	12	+·25		12	− 02	12	+ ·00	$S_4=$ ·86603
			$B_4=$	−·014	$A_4=$	+·21		$B_8=$	− ·002	$A_8=$	·00	$S_5=$ ·96593
												$1=1·00000$

The A's and B's having been thus deduced, we have $R=\sqrt{(A^2+B^2)}$. R must then be multiplied by the augmenting factors which we have already evaluated (Schedule [M]). We thus have the augmented R. Next the angle whose tangent is B/A gives ζ. The addition to ζ of the appropriate V_0+u (see Schedule [I]) gives κ, and the multiplication of R by the appropriate 1/f (see Schedule [I]) gives H. The reduction is then complete.

The following is a sample of the form used.

[O.]

Form for Evaluation of ζ, R, κ, H.

log B=	·
log A=	·
log tan ζ=	·
ζ=	·
V_0+u=	·
κ=	·
B^2=	·
A^2=	·
R^2=	·
R =	·
Augtn.=	
Augd. R=	·
1/f=	·
H=	·

A form similar to [O] serves for the same purpose in the treatment of the tides of long period, to the consideration of which we now pass; it will be seen, however, that for these tides there is no augmenting factor, and that the increase of n for $11\frac{1}{2}$ hours has to be added to ζ.

§ 10. *On the Harmonic Analysis for the Tides of Long Period.*

For the purpose of determining these tides we have to eliminate the oscillations of water-level arising from the tides of short period. As the quickest of these tides has a period of many days, the height of mean water at one instant for each day gives sufficient data. Thus there will in a year's observations be 365 heights to be submitted to harmonic analysis. In leap-years the last day's observation must be dropped, because the treatment is adapted for analysing 365 values.

To find the daily mean for any day it has hitherto been usual to take the arithmetic mean of 24 consecutive hourly values, beginning with the height at noon. This height will then apply to the middle instant of the period from 0^h to 23^h: that is to say, to $11^h\ 30^m$ at night. We shall propose some new modes of treating the observations, and in the first of them it will probably be more convenient that the mean for the day should apply to midnight instead of to $11^h\ 30^m$. For finding a mean applicable to midnight we take the 25 consecutive heights for 0^h to 24^h, and add the half of the first value to the 23 intermediate and to the half of the last and divide by 24. It would probably be sufficiently

accurate if we took $\frac{1}{25}$ of the sum of the 25 consecutive values, if it is found that the division of every 24th hourly value into two halves materially increases the labour of computing the daily means. The three plans for finding the daily mean are then

$$\left.\begin{array}{lr} \frac{1}{24}(h_0+h_1+\ .\ .\ .\ +h_{23}) \quad \ldots \quad \ldots & \text{(i)} \\ \frac{1}{24}(\frac{1}{2}h_0+h_1+\ .\ .\ .\ +h_{23}+\frac{1}{2}h_{24}) \quad \ldots & \text{(ii)} \\ \frac{1}{25}(h_0+h_1+\ .\ .\ .\ +h_{23}+h_{24}) \ldots \quad \ldots & \text{(iii)} \end{array}\right\} \quad . \quad . \quad (64)$$

And they will be denoted as methods (i), (ii), (iii) respectively. It does not, however, seem very desirable to use the third method. Major Baird considers that the use of method (i) is most convenient for the computers.

The formation of a daily mean does not obliterate the tidal oscillations of short period, because none of the tides, excepting those of the principal solar series, have commensurable periods in mean solar time.

A correction, or 'clearance of the daily mean,' has therefore to be applied for all the important tides of short period, excepting for the solar tides.

Let $R\cos(nt-\zeta)$ be the expression for one of the tides of short period as evaluated by the harmonic analysis for the same year, and let a be the value of $nt-\zeta$ at any noon. Then the 25 consecutive hourly heights of water, beginning with that noon, are—

$$R\cos a,\ R\cos(n+a),\ R\cos(2n+a)\ .\ .\ .$$
$$R\cos(23n+a),\ R\cos(24n+a).$$

In the method (i.) of taking the daily mean it is obvious that the 'clearance' is

$$-\frac{1}{24}R\frac{\sin 12n}{\sin\frac{1}{2}n}\cos(a+11\tfrac{1}{2}n)$$

In the method (ii) it is easily proved to be

$$-\frac{1}{24}R\frac{\sin 12n}{\tan\frac{1}{2}n}\cos(a+12n) \quad . \quad . \quad . \quad . \quad . \quad (65)$$

and in method (iii) it is

$$-\frac{1}{25}R\frac{\sin\frac{25}{2}n}{\sin\frac{1}{2}n}\cos(a+12n)$$

The clearance, as written here, is additive.

It was found practically in the computation for these tides that only three tides of short period exercise an appreciable effect, so that clearances for them have to be applied. These tides are the M_2, N, O tides. It was usual to compute these three clearances for every day in the year, and to correct the daily values accordingly.[1] But in following this plan a great

[1] In 1882 a mistake was noticed in the Tidal Report for 1872 in the instructions for reducing the tides of long period. It was supposed both by Mr. Roberts and by Major Baird (then in England) that this mistake had been acted on. Accordingly a

deal of unnecessary labour has been incurred, and when a simpler plan is followed it may perhaps be worth while to include more of the short-period tides in the clearances.

Professor J. C. Adams suggests the use of the tide-predicting machine for the evaluation of the sum of the clearances, and if this plan is not found to inconveniently delay operations in India, it may perhaps be tried.[1]

In explaining the process we will suppose that method (i) has been followed; if either of the other plans be adopted it will be easy to change the formulæ accordingly.

It is clear that R cos $(a+11\frac{1}{2}n)$ is the height of the tide n at $11^h\ 30^m$; and the same is true for each such tide. Hence if we use the tide-predicter to run off a year of fictitious tides with the semi-range of each tide equal to $\frac{1}{24}\sin 12n/\sin\frac{1}{2}n$ of its true semi-range, and with all the solar series and the annual and semi-annual tides put at zero, the height given at each $11^h\ 30^m$ in the year is the sum for each day of all the clearances to be *subtracted*. The scale to which the ranges are set may of course be chosen so as to give the clearances to a high degree of accuracy.

In the other process of clearance, which will be explained below, a single correction for each short-period tide is applied to each of the final equations, instead of to each daily mean.

We next take the 365 daily means, and find their mean value. This gives the mean height of water for the year. If the daily means be uncleared, the result cannot be sensibly vitiated.

We next subtract the mean height from each of the 365 values, and find 365 quantities δh giving the daily height of water above the mean height.

These quantities are to be the subject of the harmonic analysis; and the tides chosen for evaluation are those which have been denoted above as Mm, Mf, MSf, Sa, Ssa.

Let

$$\left.\begin{aligned}\delta h = {} & A\cos(\sigma-\varpi)t + B\sin(\sigma-\varpi)t \\ & + C\cos 2\sigma t + D\sin 2\sigma t \\ & + C'\cos 2(\sigma-\eta)t + D'\sin 2(\sigma-\eta)t \\ & + E\cos\eta t + F\sin\eta t \\ & + G\cos 2\eta t + H\sin 2\eta t\end{aligned}\right\} \quad . \quad . \quad . \quad (66)$$

where t is time measured from the first $11^h\ 30^m$.

Now suppose l_1, l_2 are the increments in 24 m. s. hours of any two of the five arguments $(\sigma-\varpi)t$, $2\sigma t$, $2(\sigma-\eta)t$, ηt, $2\eta t$, and that A_1, B_1; A_2, B_2, are the corresponding coefficients of the cosine and sine in the expression for δh.

Then if δh_i be the value of δh at the $(i+1)^{th}$ $11^h\ 30^m$ in the year, we may write

$$\delta h_i = A_1\cos l_1 i + B_1\sin l_1 i + A_2\cos l_2 i + B_2\sin l_2 i + \quad . \quad . \quad . \quad (67)$$

paper was presented in 1882 to the British Association by the writer of this Report upon the supposed mistake and its consequences. On his return to India, however, Major Baird found that the correct procedure had always been followed.

[1] Major Baird has sent three years of results to England in order that the method may be tested in competition with the numerical process.

And therefore

$$\delta h_i \cos l_1 i = \tfrac{1}{2}A_2\{\cos \tfrac{1}{2}(l_1+l_2)i + \cos \tfrac{1}{2}(l_1-l_2)i\}$$
$$+\tfrac{1}{2}B_2\{\sin \tfrac{1}{2}(l_1+l_2)i - \sin \tfrac{1}{2}(l_1-l_2)i\} + \ldots$$
$$\delta h_i \sin l_1 i = \tfrac{1}{2}A_2\{\sin \tfrac{1}{2}(l_1+l_2)i + \sin \tfrac{1}{2}(l_1-l_2)i\}$$
$$+\tfrac{1}{2}B_2\{-\cos \tfrac{1}{2}(l_1+l_2)i + \cos \tfrac{1}{2}(l_1-l_2)i\} + \ldots$$

Now let

$$\phi(x) = \tfrac{1}{2}\,\frac{\sin \frac{365}{2}x}{\sin \frac{1}{2}x},$$

so that

$$\phi(l_1 \pm l_2) = \tfrac{1}{2}\,\frac{\sin \frac{365}{2}(l_1 \pm l_2)}{\sin \frac{1}{2}(l_1 \pm l_2)},$$

We may observe that

$$\phi(x) = \phi(-x), \text{ and } \phi(0) = 182\tfrac{1}{2}.$$

If therefore Σ denotes summation for the 365 values from $i=0$ to $i=364$, we have

$$\left.\begin{aligned}
\Sigma\delta h \cos l_1 i &= [\phi(l_1+l_2)\cos 182(l_1+l_2) + \phi(l_1-l_2)\cos 182(l_1-l_2)]A_2 \\
&\quad + [\phi(l_1+l_2)\sin 182(l_1+l_2) - \phi(l_1-l_2)\sin 182(l_1-l_2)]B_2 + \ldots \\
\Sigma\delta h \sin l_1 i &= [\phi(l_1+l_2)\sin 182(l_1+l_2) + \phi(l_1-l_2)\sin 182(l_1-l_2)]A_2 \\
&\quad + [-\phi(l_1+l_2)\cos 182(l_1+l_2) + \phi(l_1-l_2)\cos 182(l_1-l_2)]B_2 + \ldots
\end{aligned}\right\} \quad (68)$$

In these equations there is always one pair of terms in which l_2 is identical with l_1, and since $\phi\,(l_1-l_1)=182\frac{1}{2}$, and $\cos 182\,(l_1-l_1)=1$, it follows that there is one term in each equation in which there is a coefficient nearly equal to 182·5. In the cosine series it will be a coefficient of an A; in the sine series, of a B.

The following are the equations (copied from the Report for 1872) with the coefficients inserted, as computed from these formulæ, or their equivalents:—

[P.]

Final Equations for Tides of Long Period.

	Coefft. of A	Coefft. of B	Coefft. of C	Coefft. of D	Coefft. of C′	Coefft. of D′	Coefft. of E	Coefft. of F	Coefft. of G	Coefft. of H
$\Sigma\delta h \times \cos(\sigma-\varpi)t =$	+183·05	+ 2·14	+ 0·73	+ 4·29	+ 0·77	+ 5·04	+ 4·88	− 0·34	+ 4·96	− 0·69
$\times \sin(\sigma-\varpi)t =$	+ 2·14	+181·95	− 4·15	+ 1·02	− 4·90	+ 1·07	+ 3·80	+ 0·34	+ 3·88	+ 0·69
$\times \cos 2\sigma t =$	+ 0·73	− 4·15	+183·18	+ 0·88	+ 0·61	+ 0·92	− 1·50	− 0·10	− 1·51	− 0·19
$\times \sin 2\sigma t =$	+ 4·29	+ 1·02	+ 0·88	+181·82	+ 0·92	− 0·75	+ 3·05	− 0·08	+ 3·06	− 0·17
$\times \cos 2(\sigma-\eta)t =$	+ 0·77	− 4·90	+ 0·61	+ 0·92	+183·19	+ 0·97	− 1·68	− 0·11	− 1·70	− 0·23
$\times \sin 2(\sigma-\eta)t =$	+ 5·04	+ 1·07	+ 0·92	− 0·75	+ 0·97	+181·81	+ 3·25	− 0·10	+ 3·27	− 0·23
$\times \cos \eta t =$	+ 4·88	+ 3·80	− 1·50	+ 3·05	− 1·68	+ 3·25	+182·43	+ 0·00	− 0·14	+ 0·00
$\times \sin \eta t =$	− 0·34	+ 0·34	− 0·10	− 0·08	− 0·11	− 0·10	+ 0·00	+182·57	+ 0·00	+ 0·00
$\times \cos 2\eta t =$	+ 4·96	+ 3·88	− 1·51	+ 3·06	− 1·70	+ 3·27	− 0·14	+ 0·00	+182·43	+ 0·00
$\times \sin 2\eta t =$	− 0·69	+ 0·69	− 0·19	− 0·17	− 0·23	− 0·23	+ 0·00	+ 0·00	+ 0·00	+182·57

If the daily means have been cleared by the use of the tide-predicter as above described, these ten equations are to be solved by successive approximation, and we are then furnished with the two component semi-amplitudes, say A_1, B_1 of the five long-period tides. But the initial instant of time is the first $11^h\ 30^m$ in the year instead of the first noon. Hence if as before we put $R^2 = A_1{}^2 + B_1{}^2$, and $\tan \zeta_1 = B_1/A_1$, we must, in order to reduce the results to the normal form in which noon of the first day is the initial instant of time, add to ζ_1 the increment of the corresponding argument for $11^h\ 30^m$, according to method (i), or for 12 hours according to methods (ii) or (iii).

If, however, the daily means have not been cleared, then before solution of the final equations corrections for clearance will have to be applied, which we shall now proceed to evaluate.

For this process we still suppose method (i) to be adopted.

Let n be the speed of a short-period tide in degrees per m. s. hour, and let $\psi(n) = \frac{1}{24}\frac{\sin 12n}{\sin \frac{1}{2}n}$. Then we have already seen that the clearance to δh_i, the mean height of water at $11^h\ 30^m$ of the $(i+1)^{th}$ day, will be

$$-\psi(n) R \cos [n\{24i + 11\tfrac{1}{2}\} - \zeta].$$

If we write $m = 24n$ (so that m is the daily increase of argument of the tide of short period), and $\beta = n \times 11\frac{1}{2} - \zeta$, this becomes

$$-\psi(n) R \cos (mi + \beta).$$

Hence the clearance for $\delta h_i \cos li$ is

$$-\tfrac{1}{2}\psi(n) R \{\cos [(m+l)i + \beta] + \cos [(m-l)i + \beta]\},$$

and for $\delta h_i \sin li$ is

$$-\tfrac{1}{2}\psi(n) R \{\sin [(m+l)i + \beta] - \sin [(m-l)i + \beta]\}.$$

Summing the series of 365 terms we find that the additive clearance for $\Sigma \delta h \cos li$ is

$$-R\psi(n) \{\phi(m+l) \cos [182(m+l) + \beta] + \phi(m-l) \cos [182(m-l) + \beta]\},$$

where as before

$$\phi(x) = \frac{1}{2}\frac{\sin \frac{365}{2}x}{\sin \frac{1}{2}x}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (69)$$

If Δn denotes the increase of the argument nt in $182^d\ 11^h\ 30^m$, this may now be written

$$-R\psi(n) \{\phi(m+l) \cos [\Delta n + 182l - \zeta] + \phi(m-l) \cos [\Delta n - 182l - \zeta]\},$$

If therefore $R \cos \zeta = A$, $R \sin \zeta = B$, so that A and B are the component semi-ranges of the tide n as immediately deduced from the harmonic analysis for the tides of short period, we have for the clearance to $\Sigma \delta h \cos li$

$$-[\psi(n)\phi(m+l) \cos (\Delta n + 182l) + \psi(n)\phi(m-l) \cos (\Delta n - 182l)]A$$
$$-[\psi(n)\phi(m+l) \sin (\Delta n + 182l) + \psi(n)\phi(m-l) \sin (\Delta n - 182l)]B$$

In precisely the same manner we find the clearance for $\Sigma\delta h \sin li$ to be

$$-[\psi(n)\phi(m+l)\sin(\Delta n+182l)-\psi(n)\phi(m-l)\sin(\Delta n-182l)]\mathrm{A}$$
$$+[\psi(n)\phi(m+l)\cos(\Delta n+182l)-\psi(n)\phi(m-l)\cos(\Delta n-182l)]\mathrm{B}$$

These coefficients may be written in a form more convenient for computation. For

$$\phi(m\pm l)=\frac{\sin\frac{365}{2}(m\pm l)}{2\sin\frac{1}{2}(m\pm l)}$$
$$=\tfrac{1}{2}\cos 182(m\pm l)+\tfrac{1}{2}\sin 182(m\pm l)\cot\tfrac{1}{2}(m\pm l)\quad . \quad . \quad (70)$$

Then let

$$\left.\begin{aligned} \mathrm{K}(n,l)&=\phi(m+l)+\phi(m-l)\\ \mathrm{Z}(n,l)&=\phi(m+l)-\phi(m-l)\end{aligned}\right\}\quad . \quad . \quad . \quad . \quad (71)$$

Also let

$$\left.\begin{aligned} \psi(n)\cos\Delta n&=\tfrac{1}{24}\frac{\sin 12n}{\sin\frac{1}{2}n}\cos\Delta n=\mathrm{C}(n)\\ \psi(n)\sin\Delta n&\qquad\qquad\qquad\quad=\mathrm{S}(n)\end{aligned}\right\}\quad . \quad . \quad (72)$$

The functions $\mathrm{K}(n, l)$, $\mathrm{Z}(n, l)$, $\mathrm{C}(n)$, $\mathrm{S}(n)$ may be easily computed from (70), (71), (72).

Then if we denote the additive clearance for $\Sigma\delta h \cos li$ by

$$[\mathrm{A}, n, l, \cos]\mathrm{A}+[\mathrm{B}, n, l, \cos]\mathrm{B},$$

and that for $\Sigma\delta h \sin li$ by

$$[\mathrm{A}, n, l, \sin]\mathrm{A}+[\mathrm{B}, n, l, \sin]\mathrm{B}.$$

We have

$$\left.\begin{aligned} [\mathrm{A}, n, l, \cos]&=-\mathrm{C}(n)\mathrm{K}(n,l)\cos 182l+\mathrm{S}(n)\mathrm{Z}(n,l)\sin 182l\\ [\mathrm{B}, n, l, \cos]&=-\mathrm{S}(n)\mathrm{K}(n,l)\cos 182l-\mathrm{C}(n)\mathrm{Z}(n,l)\sin 182l\\ [\mathrm{A}, n, l, \sin]&=-\mathrm{S}(n)\mathrm{Z}(n,l)\cos 182l-\mathrm{C}(n)\mathrm{K}(n,l)\sin 182l\\ [\mathrm{B}, n, l, \sin]&=\mathrm{C}(n)\mathrm{Z}(n,l)\cos 182l-\mathrm{S}(n)\mathrm{K}(n,l)\sin 182l\end{aligned}\right\}\ (73)$$

We must remark that if $\frac{1}{2}(m+l)=360°$, $\phi(m+l)$ is equal to 182·5.

This case arises when l is the tide MSf of speed $2(\sigma-\eta)$, and m the tide M_2 of speed $2(\gamma-\sigma)$, for $m+l$ is then $24\times 2(\gamma-\eta)=720°$.

The clearance of the long-period tide l from the effects of the short-period tide n requires the computation of these four coefficients. For the clearance of the five long-period tides from the effects of the three tides M_2, N, O, it will be necessary to compute 60 coefficients.

If it shall be found convenient to make the initial instant or epoch for the tides of long period different from that chosen in the reductions of those of short period, it will, of course, be necessary to compute the

values which A and B would have had if the two epochs had been identical. A and B are, of course, the component semi-ranges of the tide of short period at the epoch chosen for the tides of long period; to determine them it is necessary to multiply R by the cosine and sine of $V+u-\kappa$ at the epoch.

[Q.]

Schedule of Coefficients for Clearance of Daily Means in the Final Equations.

l =	$\sigma-\varpi$	2σ	$2(\sigma-\eta)$	η	2η
(M_2) $n=2(\gamma-\sigma)$.					
[A, n, l, cos]	−0·05557	+0·00302	+5·7393	−0·10410	−0·01465
[B, n, l, cos]	−0·17036	−0·03773	−2·9228	−0·07525	−0·07546
[A, n, l, sin]	−0·17075	+0·04170	−2·8400	−0·00176	−0·00353
[B, n, l, sin]	+0·04410	+0·01052	−5·7271	+0·00476	+0·00958
(N) $n=2\gamma-3\sigma+\varpi$.					
[A, n, l, cos]	−0·05884	+0·03680	+0·02938	−0·01760	−0·01760
[B, n, l, cos]	−0·07758	−0·22337	−0·19384	+0·00254	+0·00254
[A, n, l, sin]	−0·02059	−0·15245	−0·12210	+0·00020	+0·00041
[B, n, l, sin]	+0·11381	−0·08544	−0·08081	+0·00007	+0·00015
(O) $n=\gamma-2\sigma$.					
[A, n, l, cos]	−0·06485	+0·01673	+0·01582	−0·19240	−0·19340
[B, n, l, cos]	−0·34765	−0·07788	−0·08158	−0·18260	−0·18311
[A, n, l, sin]	−0·34523	+0·08418	+0·08748	−0·00460	−0·00926
[B, n, l, sin]	+0·04052	+0·03379	+0·03295	+0·00897	+0·01802

It may happen from time to time that the tide-gauge breaks down for a few days, from the stoppage of the clock, the choking of the tube, or some other such accident. In this case there will be a hiatus in the values of δh. Now, the whole process employed depends on the existence of 365 continuous values of δh. Unless, therefore, the year's observations are to be sacrificed, this hiatus must be filled. If not more than three or four days' observations are wanting, it will be best to plot out the values of δh graphically on each side of the hiatus, and filling in the gap with a curve drawn by hand, use the values of δh given by the

conjectural curve. If the gap is somewhat longer, several plans may be suggested, and judgment must be used as to which of them is to be adopted.

If there is another station of observation in the neighbourhood, the values of δh for that station may be inserted.

The values of δh for another part of the year, in which the moon's and sun's declinations are as nearly as may be the same as they were during the gap, may be used.

It may be, however, that the hiatus is of considerable length, so that the preceding methods are inapplicable: as when in 1882 the tidal record for Vizagapatam is wanting for 67 days. The following method of treatment will then be applicable:—

We find approximate values of the tidal constituents of long period, and fill in the hiatus, so as to complete the 365 values, with the computed height of the tide during the hiatus.

To find these approximate values we form $\Sigma\delta h \cos lt$ and $\Sigma\delta h \sin lt$ for the days of observation; next, in the ten final equations of Schedule P we neglect all the terms with small coefficients, and in the terms whose coefficients are approximately 182·5, we substitute a coefficient equal to 182·5 diminished by half the number of days of hiatus. For example, for Vizagapatam in 1882 we have $182{\cdot}5 - \frac{1}{2} \times 67 = 149$, and, e.g., $\Sigma\delta h \cos(\sigma - \varpi)t = 149A$ approximately. After the approximate values of A, B, C, D, &c., have been found, it is easy to find the approximate height of tide for the days of the hiatus. This plan will also apply where the hiatus is of short duration.

It may be pursued whether or not we are working with cleared daily means; for if the daily means are uncleared, as will henceforth be the case, we import with the numbers by which the hiatus is filled exactly those fictitious tides of long period which are cleared away by the use of the "clearance coefficients," in preparing the ten final equations for solution.

Other methods of treating a stoppage of the record may be devised. If the stoppage be near the beginning of the year, or near the end, we may neglect the observations before or after the gap, and compute afresh the 100 coefficients of Schedule P, and the clearance coefficients of Schedule Q for the number of days remaining. If the gap is in the middle we might compute the values of the coefficients of Schedules P and Q as though the days of hiatus were days of observation, bearing in mind that the formulæ are to be altered by the consideration that time is to be measured from the initial $11^{\mathrm{h}}\ 30^{\mathrm{m}}$ of the year, instead of from the initial $11^{\mathrm{h}}\ 30^{\mathrm{m}}$ of the days of hiatus.

The so computed coefficients are then to be subtracted from the values given in Schedules P and Q, and the amended final equations and amended clearance coefficients to be used.

It must remain a matter of judgment as to which of these various methods is to be adopted in each case.

§ 11. *Method of Equivalent Multipliers for the Harmonic Analysis for the Tides of Long Period.*

Up to the present time the harmonic analysis for these tides has been conducted on a plan which seems to involve a great deal of unnecessary labour. If l be the speed of any one of the five tides for which the

analysis has been carried out, in degrees per m. s. day, the values of $\cos lt$ and $\sin lt$ have been computed for $t=0, 1, 2 \ldots 364$, so that there are 730 values for each of the five tides. These 730 values have then been multiplied by the 365 δh's corresponding to each value of t, and the summations gave $\Sigma \delta h \cos lt$ and $\Sigma \delta h \sin lt$, the numerical results being the left-hand sides of one pair of the ten final equations explained in § 10. Now, it appears that this labour may be largely abridged, without any substantial loss of accuracy.

The plan proposed by Professor Adams is that of equivalent multipliers. The values of $\cos lt$ may be divided into eleven groups, according as they fall nearest to 1·0, ·9, ·8, ·7 .... ·2, ·1, 0. Then, as all the values of δh are to be multiplied by some value of $\cos lt$, and that value of $\cos lt$ must fall into one of these groups, we collect together all the values of δh which belong to one of these groups, sum them, and multiply the sum by the corresponding multiplier, 1·0, ·9, ·8, &c., as the case may be. Since there are as many values of $\cos lt$ which are negative as positive, we must change the sign of half of the δh's. This changing of sign may be effected mechanically as follows:—In the spaces for entry of the δh's, those δh's whose sign is to be unchanged are to be entered on the left side of the space if positive, and to the right if negative; when the sign is to be altered this order of entry is to be reversed. Thus in the column corresponding to each multiplier we shall have two sub-columns, on the left all the δh's which, when the signs are appropriately altered, are $+$, and on the right those which are $-$. The sub-columns are to be separately summed, and their difference gives the total of the column, which is to be multiplied by the multiplier appropriate to the column. The treatment for the formation of $\Sigma \delta h \sin lt$ is precisely similar.

The annexed form [Schedule R] is designed for entry for determination of $\Sigma \delta h \cos (\sigma - \eta)t$.

The entries of δh are to be made continuously in the marked squares from left to right, and back again from right to left. The numbers in the squares, which in the computation forms are to be printed small and put in the corner, indicate the days of observation. The rows are arranged in sets of four corresponding to each complete period of $2(\sigma-\eta)$. In the middle pair for each period the $+$ values of δh are to be written on the right, and in the rest on the left. The word 'change' opposite half the rows is to show the computer that he is to change the mode of entry. Each column, excepting that for zero, is to be summed at the foot of the page, and multiplied by the multiplier corresponding to its column. A pair of forms is required for each tide of long period; they are very easily prepared from the existing forms, in which the values of the multipliers are already computed.

[R.]

Form for Reduction of the Tide MSf.

		+ − 1·0	+ − ·9	+ − ·8	+ − ·7	+ − ·6	+ − ·5	+ − ·4	+ − ·3	+ − ·2	+ − ·1	No entries	
1	→	0	1		2				3				
	←	7		6			5				4		change
	→	8		9				10				11	change
	←	14			13			12					
2	→	15	16			17				18			
	←		21			20				19			change
	→	22	23		24			25					change
	←	29		28			27					26	
3	→	30		31			32				33		
	←		36		35				34				change
	→	37	38			39			40				change
	←	44	43			42				41			
4	→	45		46				47					
	←	51		50				49				48	change
	→	52	53			54				55			change
	←		58			57			56				
5	→	59	60		61				62				
	←	66		65			64				63		change
	→	67		68			69				70		change
	←	74	73		72			71					
Total + . Total − .			&c.				&c.				&c.	No entries	
Total . .													
Multiply .		× 1·0	× ·9	× ·8	× ·7	× ·6	× ·5	× ·4	× ·3	× ·2	× ·1	× ·0	
Results .													

Sum laterally . . . Sum of + = . . Sum of − = . .

$\Sigma \partial h \cos 2(\sigma - \eta)' =$.

§ 12. AUXILIARY TABLES DRAWN UP UNDER THE SUPERINTENDENCE OF MAJOR BAIRD, R.E.

Values of N (Long. Moon's Ascending Node) for 0^h Jan. 1, G.M.T.

Value at 0^h G.M.T. Jan. 1, 1880 = 285°·956863.

Motion per Julian year in 1880 = 19°·34146248.

Motion for 365 *days* = 19°·32822387, *and for* 1 *day* = 0°·052954.

Year	N	Year	N	Year	N	Year	N
1860	312°·7861	1875	22°·6509	1890	92°·5158	1905	162°·4335
1	293·4049	6	3·3227	1	73·1875	6	143·1053
2	274·0767	7	343·9415	2	53·8593	7	123·7771
3	254·7485	8	324·6133	3	34·4781	8	104·4489
4	235·4203	9	305·2851	4	15·1499	9	85·0677
1865	216·0391	1880	285·9569	1895	355·8217	1910	65·7395
6	196·7109	1	266·5757	6	336·4935	1	46·4112
7	177·3826	2	247·2475	7	317·1123	2	27·0830
8	158·0544	3	227·9192	8	297·7841	3	7·7018
9	138·6732	4	208·5910	9	278·4558	4	348·3736
1870	119·3450	1885	189·2098	1900	259·1276	1915	329·0454
1	100·0168	6	169·8816	1	239·7994	6	309·7172
2	80·6886	7	150·5534	2	220·4712	7	290·3360
3	61·3074	8	131·2252	3	201·1429	8	271·0078
4	41·9792	9	111·8440	4	181·8147	9	251·6795

Decrement of N since 0^h Jan. 1 up to midnight of certain days of the year.

In leap year, for all days after Feb. 28–March 1, use a mean value between that for the particular day and for the day following.

[NOTE.—*The reason for choosing midnight is because half a year after 0^h of the first day under analysis falls at midnight, and the mean value of N to be used in the tidal reductions is taken as the value of N at that date.*—G. H. D.]

Jan. 1– 2	0°·0265	May 1– 2	6°·3810	Sept. 5– 6	13°·1061
5– 6	·2383	5– 6	·5928	10–11	·3709
10–11	·5031	10–11	·8576	15–16	·6357
15–16	·7678	15–16	7·1223	20–21	·9005
20–21	1·0326	20–21	·3871	25–26	14·1652
25–26	·2974	25–26	·6519	30–31	·4300
30–31	·5621	30–31	·9166	Oct. 1– 2	·4829
Feb. 1– 2	·6681	June 1– 2	8·0225	5– 6	·6948
5– 6	·8799	5– 6	·2344	10–11	·9595
9–10	·0917	10–11	·4991	15–16	15·2243
10–11	2·1446	15–16	·7639	20–21	·4891
15–16	·4094	20–21	9·0287	25–26	·7538
20–21	·6742	25–26	·2934	30–31	16·0186
25–26	·9390	30–31	·5582	Nov. 1– 2	·1245
Mar. 1– 2	3·1508	July 5– 6	·8230	5– 6	·3363
5– 6	·3626	10–11	10·0878	10–11	·6011
10–11	·6274	15–16	·3525	15–16	·8659
15–16	·8921	20–21	·6173	20–21	17·1307
20–21	4·1569	25–26	·8821	25–26	·3954
25–26	·4217	30–31	11·1468	30–31	·6602
30–31	·6864	Aug. 1– 2	·2527	Dec. 1– 2	·7131
31–32	·7394	5– 6	·4646	5– 6	·9250
Apr. 5– 6	5·0042	10–11	·7293	10–11	18·1897
10–11	·2689	15–16	·9941	15–16	·4545
15–16	·5337	20–21	12·2589	20–21	·7193
20–21	·7985	25–26	·5236	25–26	·9840
25–26	6·0632	30–31	·7884	30–31	19·2488
30–31	·3280	Sept. 1– 2	·8943	31–32	·3018

Values of p_1 (Mean Long. of Solar Perigee) for 0^h Jan. 1.

Value at 0^h Jan. 1, 1880 = 280°·874802.
Motion per Julian year = 0°·01710693.
Motion for 365 days = 0°·01709295.

Year	p_1	Year	p_1	Year	p_1	Year	p_1
1860	280°·5327	1875	280°·7893	1890	281°·0459	1905	281°·3024
1	·5499	6	·8064	1	·0630	6	·3195
2	·5669	7	·8235	2	·0801	7	·3366
3	·5840	8	·8406	3	·0972	8	·3537
4	·6011	9	·8577	4	·1143	9	·3708
5	·6183	1880	·8748	5	·1314	1910	·3879
6	·6354	1	·8919	6	·1485	1	·4050
7	·6525	2	·9090	7	·1656	2	·4221
8	·6695	3	·9261	8	·1827	3	·4393
9	·6867	4	·9432	9	·1998	4	·4564
1870	·7038	5	·9604	1900	·2169	5	·4735
1	·7209	6	·9775	1	·2340	6	·4906
2	·7380	7	·9945	2	·2511	7	·5078
3	·7551	8	281·0116	3	·2682	8	·5249
4	·7722	9	·0288	4	·2853	9	·5420

Increment of p_1 since 0^h Jan. 1 for certain days of the year.

Motion for 1 day = 0°·00004683.

Date		Date		Date		Date	
Jan. 10	0°·00042	Apr. 10	0°·00464	July 9	0°·00885	Oct. 7	0°·01307
20	·00089	20	·00510	19	·00932	17	·01353
30	·00136	30	·00557	29	·00979	27	·01400
Feb. 9	·00183	May 10	·00604	Aug. 8	·01026	Nov. 6	·01447
19	·00229	20	·00651	18	·01072	16	·01494
Mar. 1	·00276	30	·00698	28	·01119	26	·01541
11	·00323	June 9	·00745	Sept. 7	·01166	Dec. 6	·01588
21	·00370	19	·00791	17	·01213	16	·01634
31	·00417	29	·00838	27	·01260	26	·01681

Table of I, ν, ξ, for different Values of N.

N	I	ν	ξ	N	I	ν	ξ
°	° ′ ″	° ′ ″	° ′ ″	°	° ′ ″	° ′ ″	° ′ ″
0	28 36 6	0 0 0	0 0 0	90	23 58 55	12 45 2	11 40 58
2	35 57	22 29	20 13	92	48 20	49 59	45 53
4	35 28	44 57	40 26	94	37 42	54 4	50 11
6	34 42	1 7 23	1 0 37	96	27 1	57 17	53 36
8	33 36	29 47	20 46	98	16 17	59 37	56 11
10	32 12	52 7	40 52	100	5 32	13 1 2	57 57
12	30 29	2 14 22	2 0 55	102	22 54 46	1 30	58 52
14	28 28	36 32	20 52	104	44 0	1 0	58 54
16	26 9	58 35	40 45	106	33 15	12 59 32	58 2
18	23 31	3 20 32	3 0 32	108	22 33	57 2	56 13
20	20 34	42 19	20 11	110	11 51	53 33	53 24
22	17 20	4 3 58	39 44	112	1 14	49 0	49 33
24	13 48	25 26	59 7	114	21 50 40	43 24	45 4
26	9 58	46 44	4 18 22	116	40 12	36 43	39 15
28	5 51	5 7 49	37 27	118	29 49	28 57	32 34
30	1 26	28 41	56 21	120	19 33	20 4	24 48
32	27 56 44	49 19	5 15 4	122	9 25	10 4	15 56
34	51 44	6 9 42	33 33	124	20 59 25	11 58 57	6 5
36	46 28	29 49	51 49	126	49 35	46 41	10 55 6
38	40 56	49 39	6 9 52	128	39 56	33 17	43 0
40	35 7	7 9 11	27 39	130	30 28	18 43	29 50
42	29 3	28 24	45 12	132	21 12	3 1	15 37
44	22 41	47 17	7 2 24	134	12 9	10 46 10	0 20
46	16 6	8 5 48	19 22	136	3 21	28 10	9 43 54
48	9 14	23 58	35 58	138	19 54 48	9 2	26 24
50	2 8	41 43	52 16	140	46 31	9 48 46	7 50
52	26 54 48	59 5	8 8 14	142	38 32	27 23	8 48 10
54	47 14	9 16 0	23 50	144	30 50	4 56	27 30
56	39 25	32 30	39 2	146	23 28	8 41 23	5 46
58	31 23	48 31	53 49	148	16 24	16 49	7 43 6
60	23 9	10 4 3	9 8 14	150	9 41	7 51 15	19 27
62	14 42	19 5	22 12	152	3 21	24 41	6 54 49
64	6 3	33 35	35 44	154	18 57 24	6 57 10	29 16
66	25 57 12	47 33	48 46	156	51 47	28 48	2 56
68	48 9	11 0 58	10 1 15	158	46 37	5 59 33	5 35 43
70	38 56	13 47	13 17	160	41 50	29 32	7 46
72	29 33	26 0	24 47	162	37 28	4 58 46	4 39 7
74	20 1	37 34	35 47	164	33 32	27 20	9 49
76	10 19	48 30	46 10	166	30 4	3 55 17	3 39 54
78	0 28	58 46	55 56	168	27 1	22 43	9 29
80	24 50 29	12 8 21	11 5 4	170	24 25	2 49 40	2 38 37
82	40 22	17 13	13 32	172	22 17	16 13	7 22
84	30 10	25 19	21 32	174	20 38	1 42 26	1 35 48
86	19 50	32 41	28 39	176	19 27	8 26	4 0
88	9 25	39 16	35 10	178	18 44	0 34 15	0 32 2
90	23 58 55	12 45 2	11 40 58	180	18 18 30	0 0 0	0 0 0

NOTE.—When N is negative, I has the same value as when N is positive; but ν and ξ change sign with N.

Table of $\frac{1}{f}$ and f, for different Values of I.

I	$\frac{\cos^4\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\cos^4\frac{1}{2}I}=\frac{1}{f}$		$\frac{\sin^2\omega(1-\frac{3}{2}\sin^2 i)}{\sin^2 I}=\frac{1}{f}$		$\frac{\sin\omega\cos^2\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\sin I\cos^2\frac{1}{2}I}=\frac{1}{f}$		$\frac{\sin\omega\sin^2\frac{1}{2}\omega\cos^4\frac{1}{2}i}{\sin I\sin^2\frac{1}{2}I}=\frac{1}{f}$		$\frac{\sin\omega\cos\omega(1-\frac{3}{2}\sin^2 i)}{\sin I\cos I}=\frac{1}{f}$		$\frac{\sin^2\omega\cos^4\frac{1}{2}i}{\sin^2 I}=\frac{1}{f}$		$\frac{(1-\frac{3}{2}\sin^2\omega)(1-\frac{3}{2}\sin^2 i)}{(1-\frac{3}{2}\sin^2 I)}=\frac{1}{f}$		
	$\frac{1}{f}$	f	$\frac{1}{f}$	f	$\frac{1}{f}$	f	$\frac{1}{f}$	f	$\frac{1}{f}$	f	$\frac{1}{f}$	f	$\frac{1}{f}$		
18° 18′ 30″	0·96354	1·03784	1·58617	0·63045	1·24126	0·80563	2·05992	0·48546	1·20958	0·82673	1·59903	0·62538	0·88401	1·13121	18° 18′ 30″
20	367	770	8199	3211	3971	0664	5165	8741	0816	2770	9482	2703	8441	3070	20
30	458	672	5459	4326	2951	1333	1·99763	0·50059	1·19882	3416	6720	3808	8713	2723	30
40	550	573	2792	5448	1949	2002	4552	1400	8965	4058	4031	4922	8990	2372	40
50	643	474	0196	6580	0967	2667	1·89523	2764	8066	4698	1414	6044	9271	2019	50
19 0	736	374	1·47668	7719	0003	3331	4669	4151	7185	5335	1·48865	7175	9554	1665	19 0
10	831	273	5205	8868	1·19056	3994	1·79981	5562	6321	5969	6382	8314	9842	1307	10
20	927	170	2806	0·70025	8127	4655	5452	6996	5474	6600	3964	9462	0·90134	0946	20
30	·97023	068	0468	1191	7214	5314	1077	8153	4642	7228	1607	0·70618	0430	0583	30
40	121	1·02964	1·38190	2364	6318	5971	1·66847	9935	3826	7853	1·39310	1782	0731	0216	40
50	219	861	5969	3546	5438	6627	2758	0·61441	3026	8476	7071	2955	1035	1·09848	50
20 0	318	756	3803	4737	4573	7281	1·58801	2971	2240	9095	4888	4136	1344	9476	20 0
10	419	649	1691	5935	3724	7932	4979	4525	1469	9711	2758	5325	1656	9103	10
20	520	543	1·29630	7143	2889	8583	1277	6104	0712	0·90324	0681	6522	1973	8728	20
30	622	436	7620	8358	2069	9231	1·47694	7708	1·09970	0934	1·28655	7727	2295	8348	30
40	725	328	5658	9581	1263	9877	4226	9336	9240	1541	6677	8941	2621	7967	40
50	829	219	3743	0·80813	0471	0·90522	0867	0·70989	8524	2145	4747	0·80162	2951	7584	50
21 0	935	109	1874	2052	1·09692	1164	1·37613	2668	7821	2746	2862	1392	3286	7197	21 0
10	·98041	1·01998	0049	3299	8927	1805	4460	4372	7131	3344	1022	2630	3626	6808	10
20	148	887	1·18266	4555	8174	2444	1404	6101	6453	3938	1·19225	3875	3971	6416	20
30	256	775	6525	5819	7434	3080	1·28443	7856	5787	4530	7470	5128	0·94319	6023	30
40	365	662	4824	7090	6706	3715	5570	9637	5133	5118	5755	6390	4674	5626	40
50	475	549	3161	8370	5990	4349	2785	0·81443	4490	5703	4079	7659	5032	5228	50
22 0	586	434	1537	9656	5286	4979	0083	3276	3859	6284	2441	8935	5397	4825	22 0
10	698	319	1·09949	0·90951	4593	5609	1·17461	5135	3239	6863	0840	0·90220	5766	4421	10
20	811	203	8396	2254	3911	6236	4916	7020	2629	7438	1·09275	1512	6138	4017	20
30	925	087	6878	3565	3241	6861	2446	8932	2031	8010	7745	2812	6518	3608	30

40	·99040	969	5394	4882	2581	7484	0047	0·90870	1442	8578	6248	4119	6902	3197	40
50	156	851	3942	6207	1931	8106	1·07717	2836	0864	9144	4784	5434	7292	2783	50
23 0	273	732	2521	7541	1292	8724	5455	4828	0295	9705	3352	6756	7687	2368	23 0
10	391	613	1131	8882	0663	9341	3256	6847	0·99737	1·00264	1951	8086	8086	1951	10
20	510	492	0·99771	1·00230	0043	9957	1119	8893	9188	0819	0580	9424	8493	1530	20
30	630	371	8439	1586	0·99434	1·00569	0·99042	1·00967	8648	1371	0·99238	1·00768	8904	1108	30
40	751	250	7136	2948	8833	1181	7023	3068	8117	1919	7924	2120	9322	0683	40
50	873	127	5860	4319	8242	1789	5060	5197	7596	2463	6638	3479	9745	0256	50
24 0	996	004	4611	5696	7660	2396	3150	7354	7083	3005	5378	4846	1·00174	0·99826	24 0
10	1·00120	0·99880	3388	7080	7087	3000	1292	9539	6578	3543	4145	6219	0609	9395	10
20	245	756	2189	8473	6522	3603	0·89485	1·11751	6083	4077	2937	7600	1050	8961	20
30	372	629	1015	9872	5966	4204	7726	3991	5595	4608	1753	8988	1498	8524	30
40	499	503	0·89865	1·11278	5418	4802	6014	6260	5116	5135	0594	1·10383	1952	8086	40
50	627	377	8738	2691	4878	5399	4347	8558	4644	5659	0·89458	1784	2411	7646	50
25 0	757	249	7634	4111	4347	5992	2724	1·20884	4181	6179	8344	3194	2878	7203	25 0
10	887	121	6552	5537	3823	6584	1144	3238	3725	6695	7253	4609	3351	6758	10
20	1·01019	0·98991	5490	6973	3307	7173	0·79604	5622	3276	7209	6184	6031	3831	6311	20
30	151	862	4450	8413	2798	7761	8104	8034	2835	7718	5135	7461	4317	5862	30
40	285	731	3430	9861	2297	8345	6643	1·30475	2401	8224	4106	8898	4810	5410	40
50	420	600	2430	1·21315	1803	8929	5219	2945	1975	8725	3098	1·20340	5310	4958	50
26 0	556	468	1449	2776	1316	9510	3830	5446	1555	9224	2109	1789	5818	4502	26 0
10	693	335	0487	4244	0836	1·10089	2477	7975	1142	9719	1139	3245	6333	4044	10
20	831	202	0·79543	5718	0364	0664	1158	1·40532	0737	1·10209	0188	4707	6855	3585	20
30	970	068	8617	7199	0·89897	1238	0·69871	3121	0337	0697	0·79254	6177	7385	3123	30
40	1·02110	0·97934	7708	8687	9438	1809	8616	5739	0·89944	1180	8338	7652	7922	2659	40
50	251	799	6816	1·30181	8985	2379	7391	8388	9558	1660	7439	9134	8468	2193	50
27 0	394	662	5941	1681	8538	2946	6197	1·51064	9178	2135	6557	1·30622	9021	1726	27 0
10	537	526	5082	3188	8097	3511	5031	3773	8804	2608	5691	2116	9582	1256	10
20	682	388	4238	4702	7663	4073	3893	6512	8436	3076	4840	3618	1·10151	0784	20
30	828	250	3410	6221	7234	4634	2783	9279	8075	3540	4006	5124	0729	0310	30
40	975	111	2597	7747	6812	5191	1699	1·62077	7719	4000	3186	6638	1315	0·89835	40
50	1·03123	0·96972	1799	9278	6395	5747	0640	4908	7369	4457	2381	8158	1910	9357	50
28 0	272	832	1015	1·40815	5985	6299	0·59607	7766	7024	4911	1591	9682	2514	8878	28 0
10	423	690	0245	2359	5579	6851	8597	1·70657	6686	5359	0815	1·41213	3126	8397	10
20	574	549	0·69488	3910	5180	7399	7611	3578	6353	5804	0052	2751	3748	7914	20
30	727	407	8745	5465	4785	7945	6647	6532	6025	6245	9303	4294	4378	7429	30
28 36	1·03821	0·96320	0·68298	1·46417	0·84547	1·18277	0·56071	1·78345	0·85828	1·16512	0·68852	1·45239	1·14769	0·87132	28 36 6

Report of the Committee, consisting of Mr. ROBERT H. SCOTT (*Secretary*), Mr. J. NORMAN LOCKYER, Professor G. G. STOKES, Professor BALFOUR STEWART, *and* Mr. G. J. SYMONS, *appointed for the purpose of co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year* 1861.

THE Committee, appointed at the York meeting in 1881, and reappointed at Southampton in 1882, have to report that, in his latest letter from the Mauritius, dated June 21, 1883, Dr. Meldrum informs them that, 'owing to an increase of routine work, the synoptic charts have not made much progress since March. However, one month's charts are in the hands of Messrs. A. and K. Johnston, and others will be so soon. The isobars have entailed much labour, and they have not yet been finished.

'If we cannot present any of the charts to the British Association at its next meeting, we cannot help it. For my own part I have worked hard, but I am short of assistance.'

Under these circumstances the Committee have not thought themselves justified in applying for any portion of the grant of 50*l.* placed at their disposal by the General Committee, inasmuch as none of the charts have as yet appeared.

They would, however, request reappointment, with a second renewal of the grant, inasmuch as the work is actually in an advanced stage of preparation.

Report of the Committee, consisting of Professor CAYLEY, Professor G. G. STOKES, Sir WILLIAM THOMSON, Mr. JAMES GLAISHER, *and* Mr. J. W. L. GLAISHER, *on Mathematical Tables.*

IN the Report for 1881 it was stated that the Factor Table for the sixth Million had been completed and stereotyped. The Introduction to this Million, which relates to enumerations and comparisons extending over the whole nine millions, was completed during the present year, and the volume has been published by Messrs. Taylor and Francis. The gap of three millions between the third million and the seventh million, is therefore now filled in, and the tables extend from unity to 9,000,000. The dates of publication of the nine millions are—second, 1814; third, 1816; first, 1817; seventh, 1862; eighth, 1863; ninth, 1865; fourth, 1879; fifth, 1880; sixth, 1883.

The results of the enumeration of the primes in the sixth million were given in the Report for 1881.

The Introduction to the Sixth Million, which occupies 103 pages, contains a detailed account of the enumeration of the primes in the first nine millions, with a comparison of the results with the values given by Legendre's, Tchebycheff's, and Riemann's formulæ.

The number of primes is given in each successive group of 1000 numbers from unity up to 9,000,000, and there are also similar tables for groups of 10,000; 100,000; 250,000, and 500,000. The enumeration according to centuries is also given in a series of ninety tables, showing the numbers of centuries which contain no prime, one prime, two primes, three primes, &c., in each group of 10,000 numbers; and there are similar

tables for groups of 100,000 and for the complete millions. There are also tables giving sequences of 100 or more consecutive composite numbers in the nine millions.

A short account of the results of this enumeration was given in the Report for 1881 (pp. 305–308), and it is perhaps worth while to supplement that account by giving the following list of sequences exceeding 130 in the whole nine millions, arranged in the order of their length.

0 to 9,000,000.
Sequences exceeding 130.

Lower Limit	Upper Limit	Sequence
4,652,353	4,652,507	153
8,421,251	8,421,403	151
2,010,733	2,010,881	147
7,230,331	7,230,479	147
6,034,247	6,034,393	145
7,621,259	7,621,399	139
8,917,523	8,917,663	139
3,826,019	3,826,157	137
7,743,233	7,743,371	137
6,371,401	6,371,537	135
6,958,667	6,958,801	133
1,357,201	1,357,333	131
1,561,919	1,562,051	131
3,933,599	3,933,731	131
5,888,741	5,888,873	131
8,001,359	8,001,491	131

The three formulæ which have been proposed for the approximate representation of the number of primes inferior to any given number x are:—

(i.) Legendre's formula—

$$\frac{x}{\log x - 1{\cdot}08366}$$

(ii.) Tchebycheff's or Gauss's formula—

$$\text{li}\, x, \text{ where li}\, x = \int_0^x \frac{dx}{\log x}$$

(iii.) Riemann's formula—

$$\text{li}\, x - \tfrac{1}{2}\,\text{li}\, x^{\frac{1}{2}} - \tfrac{1}{3}\,\text{li}\, x^{\frac{1}{3}} - \tfrac{1}{5}\,\text{li}\, x^{\frac{1}{5}} + \tfrac{1}{6}\,\text{li}\, x^{\frac{1}{6}} - \&\text{c.},$$

in which the general term is $\frac{1}{n}\,\text{li}\, x^{\frac{1}{n}}$, where n denotes any number not divisible by a squared factor, namely, any number of the form $a\ b\ c$ . . . where a, b, c, . . . are different primes; the sign of the term is positive when the number of the prime factors a, b, c, . . . is even, and negative when it is uneven.

The Introduction contains comparisons between the numbers of primes counted and the values given by these three formulæ, and also by the formulæ

(iv.) $$\frac{x}{\log x - 1 - \dfrac{1}{\log x}}.$$

(v.) $$\frac{x}{\log x - 1}$$

at intervals of 50,000 up to 9,000,000. The comparisons are also given for the separate groups of 50,000. The deviations are given in separate tables.

Table I., which is abridged from the more extended tables given in the Introduction, shows the numbers of primes counted and the numbers given by the formulæ (i.), (ii.), (iii.), at intervals of 100,000 up to 9,000,000. Table II. shows the deviations in the case of the three formulæ.

Table I.

x	Number of Primes			
	Counted	Calculated by		
		Riemann's formula	Tchebycheff's formula	Legendre's formula
100,000	9,593	9,587	9,630	9,588
200,000	17,985	17,982	18,036	17,982
300,000	25,998	26,024	26,087	26,024
400,000	33,861	33,852	33,923	33,854
500,000	41,539	41,530	41,606	41,533
600,000	49,099	49,091	49,173	49,096
700,000	56,544	56,557	56,645	56,565
800,000	63,952	63,945	64,037	63,955
900,000	71,275	71,266	71,362	71,279
1,000,000	78,499	78,528	78,628	78,543
1,100,000	85,715	85,737	85,841	85,756
1,200,000	92,910	92,899	93,007	92,921
1,300,000	100,021	100,019	100,130	100,045
1,400,000	107,124	107,100	107,214	107,129
1,500,000	114,152	114,146	114,263	114,179
1,600,000	121,125	121,159	121,279	121,195
1,700,000	128,140	128,141	128,264	128,181
1,800,000	135,072	135,095	135,221	135,139
1,900,000	142,029	142,022	142,150	142,070
2,000,000	148,932	148,924	149,055	148,976
2,100,000	155,806	155,802	155,936	155,858
2,200,000	162,663	162,658	162,794	162,718
2,300,000	169,512	169,492	169,631	169,557
2,400,000	176,303	176,307	176,448	176,376
2,500,000	183,073	183,102	183,245	183,175
2,600,000	189,882	189,878	190,024	189,956
2,700,000	196,647	196,637	196,785	196,720
2,800,000	203,363	203,380	203,530	203,467
2,900,000	210,109	210,106	210,258	210,197
3,000,000	216,817	216,816	216,971	216,913
3,100,000	223,493	223,512	223,668	223,613
3,200,000	230,210	230,193	230,351	230,299
3,300,000	236,901	236,961	237,021	236,971
3,400,000	243,540	243,514	243,677	243,629
3,500,000	250,151	250,155	250,319	250,275
3,600,000	256,726	256,784	256,950	256,908
3,700,000	263,397	263,400	263,568	263,529
3,800,000	269,987	270,004	270,174	270,139
3,900,000	276,611	276,597	276,769	276,737
4,000,000	283,146	283,179	283,352	283,323
4,100,000	289,774	289,750	289,925	289,899

TABLE I. (*continued*).

x	Number of Primes			
	Counted	Calculated by		
		Riemann's formula	Tchebycheff's formula	Legendre's formula
4,200,000	296,314	296,311	296,487	296,465
4,300,000	302,824	302,861	303,039	303,020
4,400,000	309,335	309,402	309,582	309,566
4,500,000	315,948	315,933	316,114	316,102
4,600,000	322,441	322,454	322,637	322,628
4,700,000	328,964	328,965	329,150	329,145
4,800,000	335,439	335,469	335,655	335,653
4,900,000	341,993	341,963	342,151	342,153
5,000,000	348,515	348,449	348,638	348,644
5,100,000	354,973	354,926	355,117	355,126
5,200,000	361,409	361,395	361,588	361,601
5,300,000	367,902	367,856	368,050	368,067
5,400,000	374,364	374,310	374,505	374,525
5,500,000	380,802	380,755	380,952	380,976
5,600,000	387,204	387,193	387,391	387,419
5,700,000	393,608	393,624	393,823	393,855
5,800,000	399,995	400,047	400,248	400,284
5,900,000	406,431	406,463	406,666	406,706
6,000,000	412,851	412,873	413,077	413,121
6,100,000	419,248	419,275	419,480	419,528
6,200,000	425,650	425,671	425,878	425,930
6,300,000	432,075	432,060	432,268	432,324
6,400,000	438,412	438,443	438,652	438,712
6,500,000	444,759	444,819	445,030	445,094
6,600,000	451,161	451,190	451,401	451,470
6,700,000	457,499	457,554	457,767	457,839
6,800,000	463,874	463,912	464,126	464,203
6,900,000	470,285	470,263	470,479	470,560
7,000,000	476,650	476,610	476,827	476,912
7,100,000	483,019	482,950	483,169	483,258
7,200,000	489,325	489,285	489,505	489,598
7,300,000	495,673	495,615	495,835	495,933
7,400,000	501,972	501,938	502,160	502,263
7,500,000	508,273	508,257	508,480	508,587
7,600,000	514,578	514,570	514,794	514,905
7,700,000	520,925	520,878	521,103	521,219
7,800,000	527,170	527,180	527,407	527,527
7,900,000	533,534	533,478	533,706	533,830
8,000,000	539,808	539,771	540,000	540,128
8,100,000	546,058	546.058	546,289	546,422
8,200,000	552,359	552,341	552,573	552,710
8,300,000	558,642	558,619	558,852	558,994
8,400,000	564,927	564,892	565,126	565,273
8,500,000	571,172	571,161	571,396	571,547
8,600,000	577,498	577,425	577,661	577,817
8,700,000	583,779	583,684	583,921	584,082
8,800,000	590,078	589,939	590,178	590,342
8,900,000	596,298	596,190	596,429	596,599
9,000,000	602,568	602,436	602,676	602,850

TABLE II.

x	Number of primes counted	Difference between numbers counted and calculated by		
		Riemann's formula	Tchebycheff's formula	Legendre's formula
100,000	9,593	− 6	+ 37	− 5
200,000	17,985	− 3	+ 51	− 3
300,000	25,998	+26	+ 89	+ 26
400,000	33,861	− 9	+ 62	− 7
500,000	41,539	− 9	+ 67	− 6
600,000	49,099	− 8	+ 74	− 3
700,000	56,544	+13	+101	+ 21
800,000	63,952	− 7	+ 85	+ 3
900,000	71,275	− 9	+ 87	+ 4
1,000,000	78,499	+29	+129	+ 44
1,100,000	85,715	+22	+126	+ 41
1,200,000	92,940	−41	+ 67	− 19
1,300,000	100,021	− 2	+109	+ 24
1,400,000	107,124	−24	+ 90	+ 5
1,500,000	114,152	− 6	+111	+ 27
1,600,000	121,125	+34	+154	+ 70
1,700,000	128,140	+ 1	+124	+ 41
1,800,000	135,072	+23	+149	+ 67
1,900,000	142,029	− 7	+121	+ 41
2,000,000	148,932	− 8	+123	+ 44
2,100,000	155,806	− 4	+130	+ 52
2,200,000	162,663	− 5	+131	+ 55
2,300,000	169,512	−20	+119	+ 45
2,400,000	176,303	+ 4	+145	+ 73
2,500,000	183,073	+29	+172	+102
2,600,000	189,882	− 4	+142	+ 74
2,700,000	196,647	−10	+138	+ 73
2,800,000	203,363	+17	+167	+101
2,900,000	210,109	− 3	+149	+ 88
3,000,000	216,817	− 1	+154	+ 96
3,100,000	223,493	+19	+175	+120
3,200,000	230,210	−17	+141	+ 89
3,300,000	236,901	−40	+120	+ 70
3,400,000	243,540	−26	+137	+ 89
3,500,000	250,151	+ 4	+168	+124
3,600,000	256,726	+58	+224	+182
3,700,000	263,397	+ 3	+171	+132
3,800,000	269,987	+17	+187	+152
3,900,000	276,611	−14	+158	+126
4,000,000	283,146	+33	+206	+177
4,100,000	289,774	−24	+151	+125
4,200,000	296,314	− 3	+173	+151
4,300,000	302,824	+37	+215	+196
4,400,000	309,335	+67	+247	+231
4,500,000	315,948	−15	+166	+154
4,600,000	322,441	+13	+196	+187
4,700,000	328,964	+ 1	+186	+181
4,800,000	335,439	+30	+216	+214
4,900,000	341,993	−30	+158	+160
5,000,000	348,515	−66	+123	+129
5,100,000	354,973	−47	+144	+153
5,200,000	361,409	−14	+179	+192
5,300,000	367,902	−46	+148	+165

TABLE II. (*continued*).

x	Number of primes counted	Difference between numbers counted and calculated by		
		Riemann's formula	Tchebycheff's formula	Legendre's formula
5,400,000	374,364	−54	+141	+161
5,500,000	380,802	−47	+150	+174
5,600,000	387,204	−11	+187	+215
5,700,000	393,608	+16	+215	+247
5,800,000	399,995	+52	+253	+289
5,900,000	406,431	+32	+235	+275
6,000,000	412,851	+22	+226	+270
6,100,000	419,248	+27	+232	+280
6,200,000	425,650	+21	+228	+280
6,300,000	432,075	−15	+193	+249
6,400,000	438,412	+31	+240	+300
6,500,000	444,759	+60	+271	+335
6,600,000	451,161	+29	+240	+309
6,700,000	457,499	+55	+268	+340
6,800,000	463,874	+38	+252	+329
6,900,000	470,285	−22	+194	+275
7,000,000	476 650	−40	+177	+262
7,100,000	483,019	−69	+150	+239
7,200,000	489,325	−40	+180	+273
7,300,000	495,673	−58	+162	+260
7,400,000	501,972	−34	+188	+291
7,500,000	508,273	−16	+207	+314
7,600,000	514,578	− 8	+216	+327
7,700,000	520,925	−47	+178	+294
7,800,000	527,170	+10	+237	+357
7,900,000	533,534	−56	+172	+296
8,000,000	539,808	−37	+192	+320
8,100,000	546,058	0	+231	+364
8,200,000	552,359	−18	+214	+351
8,300,000	558,642	−23	+210	+352
8,400,000	564,927	−35	+199	+346
8,500,000	571,172	−11	+224	+375
8,600,000	577,498	−73	+163	+319
8,700,000	583,779	−95	+142	+303
8,800,000	590,078	−139	+100	+264
8,900,000	596,298	−108	+131	+301
9,000,000	602,568	−132	+108	+282

The mean deviations for the three formulæ are respectively—

$$-9, \quad +163, \quad +171.$$

The great superiority of Riemann's formula is at once apparent; it is more accurate than Legendre's even for the smaller values of x, and it represents the numbers of primes over the whole nine millions most satisfactorily. It seems scarcely possible that a continuous formula not involving periodic terms could more accurately represent numbers which exhibit such great irregularities.

It may be remarked that Legendre's and Tchebycheff's formulæ are coincident for $x = 4{,}850{,}000$: beyond this point they steadily diverge.

In the second and third volumes of the 'Mathematische Annalen' (1870 and 1871), Meissel has determined the numbers of primes inferior

to 10,000,000 and to 100,000,000, by a method which is equivalent to actually counting them, so that his numbers should be exact. Hargreave, also, in the 'Philosophical Magazine' for 1854, had obtained by means of a similar process the number of primes inferior to 10,000,000. In the case of 10,000,000 Meissel's number is 664,580, and Hargreave's 664,633; for 100,000,000 Meissel's number is 5,761,461. Meissel is so accurate a calculator that his results are entitled to be accepted with confidence; and, taking his numbers to represent the actual numbers of primes counted, we have the following results :—

x	Number of Primes			
	Counted by Meissel	Calculated by		
		Riemann	Tchebycheff	Legendre
10,000,000	664,580	664,667	664,918	665,140
100,000,000	5,761,461	5,761,551	5,762,209	5,768,004

x	Deviations of the three formulæ from Meissel's counted numbers		
	Riemann	Tchebycheff	Legendre
10,000,000	+ 87	+ 368	+ 560
100,000,000	+ 90	+ 748	+ 6,543

The great accuracy with which Riemann's formula represents the number of primes, both at 10,000,000 and 100,000,000, is very remarkable. At 100,000,000 the function li x still affords a good approximation; and its superiority to Legendre's formula, which gives a result differing widely from the truth, is very apparent.

Assuming a formula of the form $\dfrac{x}{\log x - A}$, and supposing the constant A to be determined by making the value given by this formula agree with the actual number of primes counted for a given value of x, it would follow that Legendre's value—viz. $A = 1{\cdot}08366$—was determined from $x = 1230$.[1] The Introduction contains a table showing the variations in the value of A, according as it is determined from $x = 50{,}000$, $x = 100{,}000$ . . . . and so on, at intervals of 50,000, up to $x = 9{,}000{,}000$, and also certain results connected with the value of A. The diminution of the value of the constant as x increases is very slow, as it only varies between 1·090 and 1·072 in the whole nine millions. Taking Meissel's values for the numbers of primes counted, it is found that the value of A, as determined from $x = 10{,}000{,}000$, is 1·07110; and, as determined from $x = 100{,}000{,}000$, is 1·06397.

Denoting by $\phi(x)$ the number of primes inferior to x, it was shown by Tchebycheff that if $\log x - \dfrac{x}{\phi(x)}$ have a limit when x is infinite, that limit must be unity. It follows, therefore, that if the number of primes be represented by a formula of the form $\dfrac{x}{\log x - A}$, the limiting value of A is unity. It appears from the results just given that the approach of

[1] It is not unlikely, however, that Legendre assigned the value 1·08366 to the constant in order to represent, as nearly as possible, the results of the entire enumerations that he had then made.

A towards its limiting value is very slow. The formula (v.) was calculated for the reason just mentioned—viz. because it is the limiting form of the general expression which includes Legendre's formula.

If A be determined so that $\frac{x}{\log x - A} = \mathrm{li}\, x$, then it is found that

$$A = 1 + \frac{1}{\log x} + \frac{3}{(\log x)^2} + \frac{13}{(\log x)^3} + \&c.,$$

to which $A = 1 + \frac{1}{\log x}$ is a first approximation. It was for this reason that the formula (iv.) was calculated. For the smaller values of x, the deviations are greater than in the case of Legendre's formula, but there is not much difference between them for values of x near 9,000,000. When $x = 100,000,000$, the deviation is less than one-half of that shown by Legendre's formula.

A portion of the Introduction relates to the calculation of the logarithm integral li x, which occurs both in Tchebycheff's and in Riemann's formulæ. The methods of calculation adopted are explained, and certain values of the function Ei (x) are given, and also some corrections to Bessel's values of li x.

The convergence of Riemann's formula is very slow, and the concluding sections of the Introduction are devoted to a discussion of the magnitudes of the successive terms.

Report of the Committee, consisting of Professor CRUM BROWN (*Secretary*), *and* Messrs. MILNE-HOME, JOHN MURRAY, *and* BUCHAN, *appointed for the purpose of co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.*

A GRANT of 50*l.* was made to the Committee by the British Association in 1882 'for the purpose of co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.'

These observations were on a much more extensive scale than those of the summer of 1881. In 1882 six additional stations were established at different altitudes between the two principal stations on the top of Ben Nevis and at Fort William. These stations were so placed that observations could be made at regular intervals of half an hour during the ascent and descent; and simultaneously with these, half-hourly observations were made at Fort William. The number of observations made daily at Fort William was twenty-one, and on the top of Ben Nevis five, the latter being from 9 to 11 A.M.

In addition to the usual instrumental observations, special attention was given to noting wind, cloud, and other weather changes, and it may be added that these eye observations were carried out by Mr. Wragge with an ability and an enthusiasm worthy of the highest praise.

Owing to the excessive labour in copying these elaborate and voluminous observations from the note-books, the observations only began to be received at the Society's office in June and thereafter from time to time in July and August. On this account little more than a beginning has been made with their discussion.

From the half-hourly observations beginning with 5 A.M., the diurnal

curves for atmospheric pressure, temperature, and humidity have been calculated for Fort William. These curves are interesting and valuable as showing the eminently insular character of the climate of the region round the base of Ben Nevis from which the air is drawn which ascends its slopes on a summer's day. The curves of pressure, temperature, and humidity for the top of Ben Nevis from 9 to 11 A.M. are also highly interesting and important, especially when compared with the curves for these hours at Fort William. The degree of saturation of the atmosphere and its persistency on the top of Ben Nevis during these hours of the day is perhaps the most important meteorological feature of the climate of this elevated region: and this feature is all the more pronounced when a cyclone is advancing from the Atlantic.

This type of weather prevailed, with few and short-continued interruptions during the whole season of 1881. But in 1882, isolated periods of fine weather and well-marked anticyclones occurred in Scotland, when the atmosphere at the top of Ben Nevis passed from a state of saturation to a state of extreme dryness—a dryness indeed greater than could be found anywhere nearer than the region of the Sahara. These violent contrasts are often separated from each other by exceedingly short intervals of time and of space. It is to be noted that the extremest cases of dryness have only been observed at the very top of the mountain and were in every case accompanied by a very high temperature for that height. This peculiarity marks the Ben Nevis Observatory as admirably suited for the prosecution of some hygrometric and other physical inquiries which are so urgently called for in the present state of meteorology.

It is expected that the discussion of these observations will be completed by Mr. Buchan, and the results published, in the 'Journal of the Scottish Meteorological Society,' early next year. A copy of the 'Journal' will be sent to the British Association.

Report of the Committee, consisting of Professor SCHUSTER (*Secretary*), Sir WILLIAM THOMSON, Professor H. E. ROSCOE, Professor A. S. HERSCHEL, Captain W. DE W. ABNEY, Mr. R. H. SCOTT, Dr. J. H. GLADSTONE, *and* Mr. J. B. N. HENNESSEY, *appointed for the purpose of investigating the practicability of collecting and identifying Meteoric Dust, and of considering the question of undertaking regular observations in various localities.*

THE work of the Committee during the past time consisted chiefly in the examination of some solid residues of Himalayan ice. The ice was boiled down according to instructions of one of the members of the Committee (Mr. J. B. N. Hennessey) by a surveying party, who forwarded to the Secretary three specimens. One of these came from the Gamukdori Pass, on the watershed between the Indus and the Kishenganga (lat. 35° 5′, long. 74° 13′), at an altitude of 13,400 feet; and two from the Shokari Pass (lat. 35° 0′, long. 74° 38′, altitude 14,700 feet). There is no human habitation near either of these places. The amount of snow boiled down was about 25 cubic feet, and the solid residue was about the same in all three cases, weighing a little over ·1 gramme. It consisted chiefly of organic matter, due principally to birds, but a quantity of magnetic particles was also found in them. The magnetic matter in great part is due to ferruginous rocks, and must have been brought by the wind to the

place where it was found; but all the specimens also contained (1) spherical particles of magnetic oxide of iron, and (2) small particles of iron, partly metallic, of the shape given in last year's Report. These are probably of a meteoric origin. The Committee is still pursuing the work for which it was appointed.

Report of the Committee, consisting of Captain ABNEY (*Secretary*), Professor W. G. ADAMS, Professor G. C. FOSTER, Lord RAYLEIGH, Mr. PREECE, Professor SCHUSTER, Professor DEWAR, Mr. VERNON HARCOURT, *and* Professor AYRTON, *reappointed for the purpose of fixing a Standard of White Light.*

THE Committee have received the draft of a report from their Secretary. As the subject has recently received much attention from different sides, and as the Committee hope to increase the value of their report by an extension and further discussion of the experiments, they prefer to defer the publication of their full report until next year. To carry out the intention of the Committee a grant of 20*l.* will be required.

Report of the Committee, consisting of Professors WILLIAMSON, FRANKLAND, ROSCOE, CRUM BROWN, *and* ODLING, *and* Messrs. J. MILLAR THOMSON, V. H. VELEY, *and* H. B. DIXON (*Secretary*), *appointed for the purpose of drawing up a statement of the varieties of Chemical Names which have come into use, for indicating the causes which have led to their adoption, and for considering what can be done to bring about some convergence of the views on Chemical Nomenclature obtaining among English and foreign chemists.*

THE Committee have been as yet unable to complete their report on Chemical Nomenclature. A large part of the work of drawing up in tabular form the varieties of chemical names which have come into general use in England and abroad has been accomplished, but the Committee wish to extend the work before making their report, and for this purpose desire to be reappointed for another year, with the addition of the names of Mr. Japp, Professor Dewar, Mr. Vernon Harcourt, and Mr. Forster Morley.

Report of the Committee, consisting of Professors ODLING, HUNTINGTON, *and* HARTLEY (*Secretary*), *appointed for the purpose of investigating by means of Photography the Ultra-Violet Spark Spectra emitted by Metallic Elements, and their combinations under varying conditions. Drawn up by* Professor W. N. HARTLEY.

The disappearance of short lines.—It was shown in a former Report of this Committee (Southampton Meeting) that the spectra of metallic solutions were the same as those from metallic electrodes line for line, in most cases even short and weak lines being reproduced. The principal difference observable in the two spectra was a lengthening of the short lines

when spectra were taken from solutions, so that discontinuous lines became long or continuous lines.

A few instances of short lines disappearing have also been noticed, but such disappearances occur only when the lines are so short, mere dots in fact, that no solution can contain a quantity of the metal sufficient to yield an image of them, unless the rest of the spectrum be greatly over-exposed. Certain very short lines in the spectrum of zinc are an example of this. Very short lines in the spectrum of aluminium were not reproduced by solutions of the chloride unless the solutions were highly concentrated. It may thus be seen that the quantity of metal present in the compound thus determines the presence of the lines.

The lengthening of short lines.—It was remarked that in certain cases metallic electrodes showed a different spectrum according to whether the spark was passed between dry or wet electrodes. Thus it was pointed out that when iridium electrodes are moistened with calcium chloride, discontinuous lines which are very numerous in this spectrum became continuous, and on further examination into this matter it has been found that even moistening with water has the same effect. Hence the supposition, of which there seemed some possibility but no proof, that a chloride of the metal was formed was found to be untenable. The very short lines in the spectrum of zinc were lengthened by the action of water upon the electrodes. It has now been proved beyond doubt that this peculiar variation in the spectra is caused by the cooling action of the water upon the negative electrode, which in effect is the same as a strengthening of the spark, since by heating the electrodes a reverse action is the result.

Alterations in the spectrum of carbon.—As already stated in the previous Report, graphite electrodes have been generally employed for the purpose of producing spark spectra from solutions. A portion of the work in connection with this subject included an investigation of the effect of water and of saline solutions in varying the spectrum of carbon. It will of course be readily seen that, as carbon is capable of combining with oxygen and nitrogen, different spectra might be obtained by making one or other of those gases the atmosphere surrounding the electrodes, but it is not so easy to explain why graphite points should give two different spectra in air when dry and a third spectrum when moistened with water, the same spark conditions being maintained. Three such spectra have been photographed, but without the aid of maps their peculiarities are not capable of exact description. The maps which were drawn were presented to the Royal Society together with a communication on this subject, three months since, so that they are not at present available. It may be said, however, that the difference between the spectra taken from dry electrodes in air consists in the omission of a certain number of the less refrangible lines, which have undoubtedly been identified with carbon.

Spectra of the non-metallic constituents of salts.—A long series of experiments has been made with the object of determining the non-metallic elements which are capable of yielding spark spectra when in combination with the metals. Chlorides, bromides, iodides, sulphides, nitrates, sulphates, selenates, phosphates, carbonates, and cyanides yield nothing. On the other hand, solutions in hydrochloric acid of arsenites, arseniates, and antimoniates yield spectra of arsenic and antimony respectively. Borates and silicates in solution yield very characteristic spectra of the non-metallic constituents; but if the solutions be prepared from sodium

salts, the lines of the metal do not appear in the case of borates, and only the strongest line of sodium ($\lambda=3301$) can be observed in the spectrum of silicates, even when concentrated solutions are used. These are the first spectra of boron and silicon obtained from metallic salts. Their lines are the following:—

Boron. Wave-lengths	Silicon. Wave-lengths
3450·1	2881·0
2497·0	2631·4
2496·2	2541·0
	2528·1
	2523 5
	2518·5
	2515·5
	2513·7
	2506·3
	2435·5

In Messrs. Liveing and Dewar's map of the carbon spectrum,[1] and in the list of the carbon lines, and in the map of the iron spectrum,[2] a number of lines are given which are absent from the photographs of the spectrum of graphite published in the Transactions of the Royal Dublin and in the Journal of the Chemical Society.[3] Many hundreds of spectra taken between graphite poles have failed to show a trace of these lines, and as the spectra have been photographed under varying conditions it is scarcely likely that the lines in question are really carbon lines. They have now been identified with the spectrum of silicon. The following are their wave-lengths:—

Lines from the Carbon Spectra (Liveing and Dewar) Spark	Arc	Silicon (Hartley) Spark
—	2881·1	2881·0
2541·0	—	2541·0
2528·2	2528·1	2528·1
2523·6	2523·9	2523·5
2518·7	2518·8	2518·5
2515·8	2515·8	2515·5
2514·0	2514·1	2513·7
2506·3	2506·6	2506·3
—	2478·3	—
—	2434·8	2435·5

From this it appears that in the spectrum of the arc, carbon yields but one line in the ultra-violet, wave-length 2478·3.

The spectrum of beryllium.—The researches made for the purpose of this Report have been useful in furnishing evidence leading to a determination of the probable position of beryllium among the elements. It has been proved that the spectra of metallic solutions are identical with those of the metals themselves, and it is therefore obvious that characteristic spectra may be obtained from concentrated solutions of nitrates or chlorides when metallic electrodes are not procurable, just as is the case with visible spectra. It was resolved to photograph the spectrum of beryllium as obtained from its chloride, in order to observe the character of its lines and the manner of their grouping. The following were the lines observed:—

[1] *Proc. Roy. Soc.* vol. 33, p. 403. [2] *Phil. Trans.* vol. 174, Part I. 1883.
[3] *Transactions*, vol. 41, p. 90.

SPECTRUM OF BERYLLIUM.

Wave-lengths	Description
3320·1	Strong sharp
3129·9	Very strong, extended
2649·4	Strong sharp
2493·2	Strong sharp
2477·7	Strong sharp

The first two numbers differ slightly from those given in the 'Journal of the Chemical Society,'[1] but they are believed to be the more accurate. The previous measurements of the lines of beryllium were two given by Thalén[2] with wave-lengths 4487 and 4575, and two lines very close together given in Cornu's map of the solar spectrum, wave-lengths 3130 and 3130·4. It will be observed that in the spark spectrum there is only one line corresponding to the first of the latter, with wave-length 3129·9. There is probably a difference in this case between the arc and the spark spectrum, because there is no difficulty in distinguishing between two lines differing by 0·4, and under various conditions two lines have never been observed at this point in the spark spectrum. On the other hand such differences are by no means unusual.

Regarding the views held by Emerson Reynolds, Nilson and Pettersson, and Brauner on the subject of beryllium, there may be a want of harmony in detail, but they at least agree in assigning a value, not greater than 13·8 and not less than 9·2, to its atomic weight. The former number implies that the metal is a triad, the latter that it is a dyad. In the former case it must belong either to the series of elements of which aluminium, gallium, and iridium are members, or to a sub-group of rare earth metals to which yttrium and scandium belong. In attempting to accommodate the element with a position in either series we are met by a serious difficulty—viz., that not only is the atomic weight not in keeping with the periodic law (a point which cannot be discussed here), but its spectrum is altogether different from the spectra typical of either class. There is a periodic variation in the spectra of the elements as well as in their atomic weights and chemical properties, and we cannot put the periodic law out of mind in considering the position of beryllium. Now the spectra typical of the triad group, of which aluminium and indium are the first and third terms, consist of three pairs of lines harmonically related, the intervals between the individuals of each pair increasing with increased refrangibility of the rays in each spectrum, while the intervals between the individuals in each pair in different spectra increase with the increase of atomic weight. The interval between each pair of lines contains an isolated ray. As the atomic weight of beryllium is less than that of aluminium, it should have a spectrum in which the same grouping appears, but the intervals between the pairs of lines should be shorter, and the individuals of each pair should be closer together. The lines of beryllium are not characteristically grouped like those of aluminium and indium, it cannot therefore belong to this series of elements. If we attempt to classify beryllium in a manner which accords with Nilson and Pettersson's views,[3] the elements scandium and yttrium, with atomic weights 44 and 89 respectively, must yield spectra typical of the series, and the similarity between the spectra of the two metals,

[1] June, 1883, p. 316. [2] *Watt's Index of Spectra.*
[3] *Proc. Roy. Soc.* 1880, vol. 31, p. 37.

beryllium and scandium, must be as close as that between scandium and yttrium. Now Thalén's spectra of scandium and yttrium, though both totally unlike the spectrum of any other element, have many characters in common;[1] both spectra contain highly characteristic groups of lines in the orange and yellow regions, the lines or bands degrading towards the red, and the number of lines which have been measured are no fewer than 103 and 90 respectively. From these two spectra, that of beryllium is entirely different, as well in the character and grouping as in the number of the lines. Of the remaining rare earth-metals at present known, cerium is a tetrad, didymium is a pentad, and lanthanum a triad; their spectra are quite dissimilar from that of beryllium. In consideration of these facts it is impossible to classify the spectrum of beryllium along with the spectra of the rare earth metals of the triad group.

Let us now consider the question of the dyad groups. On the assumption that beryllium has an atomic weight of 9·2, there is no difficulty in placing it at the head of the second series of elements in which position it stands in the same relation to the sub-groups—magnesium, zinc, cadmium, and calcium, strontium, barium—that lithium occupies with regard to sodium, potassium, rubidium and copper, silver, mercury.

Its position is also similar to that of boron and of carbon in relation to the triad and tetrad metals. The spectra belonging to magnesium, zinc, cadmium, have a very definite constitution; they consist of—1. A single line; 2. A pair of lines; 3. Three to four groups of triplets; 4. A quadruple group; and 5. A quintuple group of lines. The intervals between the individual lines in the different groupings increases with the increase in the atomic weights of the elements. In fact these spectra present a considerable addition to the body of evidence in support of the view that elements whose atomic weights differ by an approximately constant quantity, and whose chemical properties are similar, are truly homologous bodies, or in other words are the same kind of matter in different states of condensation. Their particles are vibrating in the same manner, but with different velocities.

In the spectra of the metals calcium, strontium, and barium, successive pairs of lines are a strong feature, in addition to which there are some other groups in the spectrum of barium. The individuals of each pair are separated by smaller intervals the more refrangible the lines and by longer intervals the higher the atomic weights. It cannot be said that the spectrum of beryllium is similar in constitution to either of these groups of elements, which it should be if it strictly belonged to one of them. There is some slight resemblance in character to the spectrum typical of the calcium group, beryllium having two pairs of lines, the individuals of the first or less refrangible pair being separated by a greater interval than those of the second pair. It is a spectrum analogous to that of lithium, having but few lines and no striking resemblance to the elements which follow in the series because it stands at the head of two sub-groups. Hence it has been concluded that beryllium is the first member of a dyad series to which probably calcium, strontium, and barium are more strictly homologous than magnesium, zinc, and cadmium. It is to be understood that this is a conclusion drawn from one view only, and is open to correction or modification

[1] *Kongl. Svenska Akademiens Handlingar*, vol. xii. p. 4, also *Comptes Rendus* vol. 91, p. 45.

when fresh facts shall have been discovered, but so far, the views of Professor Emerson Reynolds and Dr. Brauner are maintained by these spectrum observations, for beryllium is shown to be quite out of place among the triad elements, including those belonging to the rare earths.

Report of the Committee, consisting of Professors W. A. TILDEN *and* H. E. ARMSTRONG (*Secretary*), *appointed for the purpose of investigating Isomeric Naphthalene Derivatives.*

SINCE the appointment of the Committee, the investigation has been prosecuted mainly in three directions:—1. A careful study has been made of Betanaphthol and especially of the sulphonic acids derived therefrom; and peculiarities have come to light which confirm the view that the behaviour of Betanaphthol is in many respects different from that of the phenols which have hitherto been investigated. 2. The isomeric naphthalenedisulphonic acids have been further examined and much has been done towards establishing the nature of the conditions under which they are formed. 3. The isomeric naphthalenedisulphonic acids have been converted into corresponding Dichloronaphthalenes and Dihydroxynaphthalenes and the comparative study of the latter has been commenced.

As, however, it is not desired to describe individual compounds, but to study comparatively the behaviour of several members of certain classes of isomeric naphthalene derivatives, and as much remains to be done before a connected account can be given of the results of the investigation, the Committee consider it desirable to postpone their report until next year, when, it is hoped, it will be possible to carry out their intention; and therefore ask to be reappointed. The grant placed at their disposal has been entirely expended in the purchase of material.

Report of the Committee, consisting of Professor VALENTINE BALL, Professor W. BOYD DAWKINS, Dr. J. EVANS, Mr. G. H. KINAHAN, *and* Mr. RICHARD J. USSHER (*Secretary*), *appointed for the purpose of carrying out Explorations in Caves in the Carboniferous Limestone in the South of Ireland.*

DURING the past year your Committee have aimed at the exploration of Shandon Cave, near Dungarvan, which yielded remains of extinct post-Pleiocene mammalia in 1859 and in 1875. The exploration conducted in the latter year by the late Professor A. Leith Adams was discontinued by him in consequence of the danger presented by the loose impending rocks forming the roof, some of which have sunk down upon the ossiferous beds. The first step to the exploration has been the removal of this dangerous roof, which tended to fall away in shelves.

During the latter part of 1882 circumstances rendered it unadvisable to move in the matter of Shandon Cave; but in January last your Committee entered into an arrangement with the occupier of the ground to quarry away a specified portion of the cliff over the cave's mouth, first

removing the fence and the soil above it. Two or more men were kept almost constantly at this work from February during the spring and summer months, and the large amount of stone quarried has been carted away. But though little now remains to be done to put the cave into a fit state for exploration of its ossiferous deposits, it has not been possible hitherto to commence the latter operation.

The work done has been inspected by Mr. Duffin, the county surveyor. The Committee have applied 5*l*. in payment for this, and retain 5*l*. for current expenses, the balance of the grant—namely, 10*l*.—remaining undrawn. The Committee beg leave to apply for a fresh grant of 50*l*., to reap the fruits of what has been done and to explore the portions of the cave thereby laid bare. They hope before the next meeting of the Association to report upon the examination of the ossiferous beds that have hitherto been inaccessible without the preliminary work of removing the roof, and also to explore any other Carboniferous Limestone caves that they may have an opportunity of examining in Ireland.

Report of the Committee, consisting of Professor A. H. Green, Professor L. C. Miall, Mr. John Brigg, *and* Mr. James W. Davis (*Secretary*), *appointed to assist in the Exploration of Raygill Fissure, Yorkshire.*

The fissure occurs in an anticlinal of limestone in Lothersdale, near Skipton. It was formerly open to the surface, and from thence extended in a southerly direction, and with only a slight inclination from a vertical line. During repeated operations of quarrying it has been from time to time cut across on the face of the quarry, each exposure being at a lower level and exhibiting some new feature in the character of the clays and sands which have been carried into it. In December 1879 the Council of the Yorkshire Geological and Polytechnic Society decided that it was desirable that steps should be taken to secure a thorough investigation of the fissure and its contents, and appointed a Committee, consisting of Professors Green and Miall and of Messrs. Brigg and Davis, to carry out the exploration. The Committee decided to apply to the members of the society for subscriptions to enable them to carry on the work, and a fund of 60*l*. was obtained, separate from the ordinary income of the society, and operations at the quarry were commenced in June of the following year. Mr. Spencer, the proprietor, and Mr. Todd, his manager, placed men skilled in the class of work required at the disposal of the Committee, and Mr. Todd kindly undertook the management of the work.[1] The fissure opened into the face of the quarry towards the north, the limestone dipping at a sharp angle into the hill southwards. The opening of the fissure when the operations were commenced was 27 feet 6 inches from top to bottom, and about 9 feet across. It was situated about 60 feet below the surface of the ground, and the same distance above the floor of the quarry. The section exposed in the opening showed the following beds:—

[1] At the meeting of this Association at York a grant of 20*l*. was made towards the work of exploration.

	ft.	in.
Limestone roof		
1. Laminated clay	9	0
2. Sand, with layers of sandy clay, and numerous angular and subangular stones . . .	11	6
3. Sandy clay with rounded stones . . .	7	0

The uppermost stratum was composed of fine unctuous laminæ of bluish clay, which turns a brown colour by exposure to the atmosphere; between each lamina of clay there is a minute layer of very fine sand, by means of which thin sheets of clay can be removed of considerable size. The middle stratum of sand contains numerous boulders of stone, mostly subangular in form. These, so far as the Committee have had an opportunity of examining them, are composed principally of limestone and grit rock. No bones have been found in this bed. The third or lowest stratum is a brown sandy clay, containing numerous well-rounded water-worn pebbles of limestone and sandstone, apparently derived from rocks occurring in the neighbourhood. Intermixed with these, especially near the base of the section, are numerous bones and teeth. The sands and clays surrounding or forming the matrix of the bones are cemented together, forming a hard mass enclosing the animal remains. The bones, for the most part, when newly exposed, are very soft and friable, and being cemented in the hard matrix, it rarely happens that a bone can be secured which retains its original form; they split and break in any direction with the matrix, and remain imbedded in it. Both the pebbles and the external surface of the bones are of a dark chocolate colour.

The material was removed from the base of the quarry backwards, and a considerable number of bones were found in the lowest stratum exposed. After penetrating for a distance of 15 feet, the fissure was terminated in this direction by a vertical wall of limestone, well rounded and waterworn; and from this point the fissure descended almost vertically for a distance of about 27 feet. The limestone, which formed a wall between the fissure and the face of the quarry, constantly increased in thickness as the work of excavation proceeded. It had to be removed, and at 27 feet below the lower surface of the opening, at the commencement, the fissure extended 19 feet into the limestone. The vertical fissure is filled up for a portion of its depth by bone-earth, similar in character to No. 3 in the section given above, but towards the bottom there is in front a large mass of yellow clay with large angular blocks of limestone. The space betwixt this clay and the southern wall is filled with bone-earth. At a depth of 3 or 4 feet below the level of the fissure, or 31 feet from the top of the opening, there was found the broken pieces of a large tusk of an elephant; a portion is missing and could not be found. Along with the tusk were numerous other bones of the elephant, including several large teeth. There were also bones, well-preserved teeth and tusks of the hippopotamus, the latter mostly in fragments, only two specimens being found which were perfect. Teeth of the hyæna were numerous, and in most instances seemed to be those of adult animals, the points being well worn. Examples of *Rhinoceros leptorhinus* and the broken horn of a roebuck (*Cervus capreolus*) were found in the upper part of the cave. Except the teeth, which are generally in a good state of preservation, the remaining bones were nearly all fragmentary, and so imbedded in the hard cemented matrix that it is almost impossible to ascertain to what animal they belonged. Below the point indicated above the fissure branches in two directions. One proceeds eastwards, and is

nearly horizontal; it is sufficiently open for a man to creep along a distance of 25 feet, where a mass of fallen limestone prevents further progress, but beyond this mass an additional distance could be distinguished of about 12 or 14 feet. The second branch extends in a southerly direction, and appears to fall rapidly. It is only accessible for a distance of 3 or 4 yards. Where the roof and sides of the fissure are exposed they show signs of erosion; the surfaces are smoothened and the corners of the limestone rounded off by running water. There is very little appearance of stalagmite having been found.

The following section will serve to explain the relative position of the beds hitherto worked upon. It represents a section across the fissure in a north and south direction:—

1. Laminated clay.
2. Sand and sandy clay with boulders, without stratification.
3. Brown sandy clay, with rounded stones blackened, and numerous bones of animals, unstratified (bone-earth).
4. Stiff yellow clay, with large masses of angular limestone.

The stiff yellow clay at the lower part of the excavated portion occupied a large area in front of the fissure, the bone-earth being behind. Mr. Todd states that in the uppermost portion of the fissure, near the surface, there was a considerable amount of similar yellow clay. The excavation was continued for a short distance into the horizontal branch of the fissure, proceeding in an easterly direction. The opening is large, and, as stated, contains a quantity of material reaching almost to the roof. A number of bones and teeth have been found, similar to those obtained from bone-earth at a higher elevation. In this part of the fissure, in addition to the remains of elephas, hyena, hippopotamus, rhinoceros, bear, the bones of some smaller animal, probably fox, and the bones of a bird, there were found teeth of the lion.

The work had now proceeded so far that it was thought desirable to postpone the operations of your Committee, to enable Mr. Spencer to quarry the limestone in front of the fissure, and during the past year a great mass of limestone has been removed. Whilst quarrying the limestone above the site of the fissure a branch was found to extend in a south-westerly direction almost vertically to the surface, forming with the excavated one a Y-shaped junction. It was filled up with clay and sand, and a few bones were found. The bones were much decomposed, and broke into fragments while the attempt was being made to extricate them.

Your Committee hope that during the coming winter the proprietor of the quarry, Mr. Spencer, will be able to remove all the limestone which still impedes the entrance to the fissure and the continuance of the work, and that the excavation may be resumed during the early part of next spring.

In conclusion we cannot too heartily express our indebtedness to Mr. Spencer and to Mr. Todd for the kind and generous manner in which they have assisted in the excavation.

Eleventh Report of the Committee, consisting of Professors J. Prestwich, W. Boyd Dawkins, T. McK. Hughes, *and* T. G. Bonney, Dr. H. W. Crosskey, Dr. Deane, *and* Messrs. C. E. De Rance, H. G. Fordham, J. E. Lee, D. Mackintosh, W. Pengelly, J. Plant, *and* R. H. Tiddeman, *for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation. Drawn up by* Dr. Crosskey, *Secretary.*

The Committee is able to record many additional facts respecting erratic blocks, in its report for the present year. The Committee continue to confine their work to recording the observations made, and do not attempt to offer theoretical explanations. The information collected will enable the distribution of the erratic blocks to be mapped with considerable accuracy, and it is ultimately intended to tabulate the results obtained.

This work, however, must necessarily be delayed in consequence of the constant discovery of fresh groups of erratic blocks.

So many new facts are reported to the Committee year by year from different parts of the country, that it would lead to mistaken generalisations to make any attempt at complete classification.

Yorkshire.—The Committee have received from Mr. James E. Westby, of Sheffield, the subjoined report on erratic blocks found at Crosspool:—

Crosspool is about one and a half miles west of Sheffield, on the rising ground to the left of the Sheffield and Glossop turnpike road, and lies on shales underlying the Middle Rock (Gannister Series) of the Lower Coal Measures.

To the east the ground slopes towards Sheffield; to the west it begins to slope to the Rivelin Valley. To the north-east the Middle Rock sandstone forms a bold escarpment; while the land from Crosspool rises quickly to the south-west up to Sandygate.

The heights of the various points above sea-level are: Lydgate, 800 ft.; River Rivelin, 350 ft.; Crosspool, 730 ft.; Sandygate, 850 ft.

To the west of a line drawn from Sandygate, through Crosspool to Lydgate, the drainage and fall is towards the River Rivelin, while on the eastern side of the same line the rainfall is ultimately drained into the River Porter, both of which streams are tributaries of the River Don. Lying on the high land forming the outer edge of the drainage area of the River Porter, on its north side, there is a triangular patch of flat ground, now very uneven, having been worked for brick-making, over which lie scattered blocks and boulders of various sizes, which have been exposed and left in their present position by the workmen, who have generally got all the available clay.

In the sections exposed the clay containing these blocks varies from 2 ft. down to 10 and 12 ft. in depth, differing much from the ordinary surface-clays of the district, which are generally the decomposed coal-measure shales.

On the *local* blocks, which vary from large masses weighing 3 or 4 tons, down to small pebbles, there are irregular scratches, but several of the erratics, which are scarce—probably constituting but $\frac{1}{500}$th part of the coarser materials—have the striæ finely and regularly marked along the longer axis of the stone in decided grooves.

There do not appear to be any erratics on the neighbouring highlands, and the adjoining fields have not been worked so as to reveal sections. It is probable, however, that a much larger area than the one here detailed once existed, for a large felstone boulder was found in the Porter valley, near Ecclesall Road, Sheffield, a distance of $1\frac{1}{2}$ miles S.W. from Crosspool, and 600 feet lower in level, in composition and appearance identical with several of the Crosspool boulders.

With the exception of the erratics catalogued, the large boulders consist either of millstone grit or coal-measure sandstones, which are local rocks; the millstone grit series appearing only $\frac{1}{4}$ mile to the west, while the grit series crops out in the Rivelin valley.

Petrologically, however, many of these boulders differ from the rocks in the immediate neighbourhood, although they have evidently been derived from the same measures.

Some of the gannister, *e.g.*, is compact, fine-grained and nearly white, but its identity is shown by a new fracture revealing traces of stigmaria.

The following is a list of the principal erratics :—

The specimens have been named by Professor Bonney.

Although the size of some of the specimens is much less than that of those usually catalogued as boulders, yet their peculiarities render the list of value.

1. A small well-rounded boulder, rather flat, fine scratches on all sides in the direction of the longer axis. Porphyritic tuff, 6 in. $\times$ $3\frac{1}{2}$ in. $\times$ 2 in.

2. Roughly rectangular, smoothed angles little rounded. Felstone, 1 ft. 2 in. $\times$ 9 in. $\times$ 9 in.

3. Irregular shape, ends rounded. Quartz-felsite with hornblende, 2 ft. 6 in. $\times$ 2 in. $\times$ 1 in.; 30 in. $\times$ 24 in. $\times$ 20 in.

4. Subtriangular, rounded, and smoothed. Felstone, 7 in. $\times$ 7 in. $\times$ 6 in.

5. Rounded ends, surfaces nearly flat. Felsite, 1 ft. 1 in. $\times$ 7 in. $\times$ 4 in.

6. Rhomboidal, with sharp angles and flat faces. Indurated tuff, 8 in. $\times$ 4 in. $\times$ 4 in.

7. Rounded, flattish oval. Tuff much decomposed, 6 in. $\times$ 4 in. $\times$ 2 in.

8. Subangular, angles well rounded. Quartz-felsite with a little hornblende, 7 in. $\times$ 4 in. $\times$ 3 in.

9. Rectangular, angles sharp. Grey magnesian limestone, 4 in. $\times$ 3 in. $\times$ 3 in.

10. Subtriangular, rounded and smooth. Cherty magnesian lime, 7in. $\times$ 6 in. $\times$ 4 in.

11. Long roughly triangular, ends rounded, much decomposed. Felstone, 1 ft. $\times$ 4 in. $\times$ 4 in.

12. Roughly rectangular, somewhat rounded at one end. Felstone and vein stuff, 2 ft. $\times$ 1 ft. $\times$ 10 in.

13. Rounded oval boulder, smoothed. Quartz-felsite. 8 in. $\times$ 5 in. $\times$ 5 in.

14. Flat disc, rounded edges. Ice scratched on both sides. Indurated tuff, 6 in. × 4 in. × $1\frac{1}{2}$ in.

15. Rounded, somewhat oval, smooth, and with ice scratches in the direction of the longer axis. Felstone, 8 in. × 5 in. × 3 in.

16. Wedge-shaped, one side rounded as if from a large boulder. Quartz-felsite, 10 in. × 6 in. × 3 in.

17. Irregular rounded. Compact dark felstone, 1 ft. 2 in. × 10 in. × 7 in.

18. Smooth boulder. Ice-scratched felstone, 7 in. × 4 in. × 4 in.

19. Rectangular, angles sharp. Slaty rock, 6 in. × 4 in. × 4 in.

20. Rounded and worn. Sandstone, with imperfect casts of brachiopods. 9 in. × 6 in. × 6 in.

21. Rounded and smoothed, somewhat oval. Felstone, without quartz, 10 in. × 6 in. × 4 in.

22. Rounded pebble. Quartzose, 2 in. × $1\frac{1}{2}$ in. × 1 in.

23. Prismatic flat, smooth face, angles worn. Porphyritic tuff, 10 in. × 6 in. × 3 in.

24. Rounded pebble. Vesicular felsite, $1\frac{1}{2}$ in. × 1 in. × $\frac{3}{4}$ in.

25. Wedge shape, one face flat, the other rounded, as if from a large block. Porphyritic quartz-felsite, 1 ft. × 8 in. × 4 in.

26. Rectangular block, angles sharp. Magnesian limestone, 1 ft. 4 in. × 8 in. × 6 in.

27. Irregular, subangular. Rhyolite, 6 in. × 4 in. × 4 in.

28. Flat, sides and angles worn. 'Porphyritic' tuff, 10 in. × 8 in. × 3 in.

29. Rhomboidal, angles sharp. An altered rock, 9 in. × 4 in. × 4 in.

30. Subangular and irregular. An altered Silurian grit? 8 in. × 5 in × 3 in.

31. Smooth rounded pebble. Quartzose, 3 in. × 2 in. × 2 in.

32. Prismatic, triangular and smooth. Rhyolite, 4 in. × 2 in. × 2 in.

33. Smooth pebble. Probably from Bunter. Quartzite, 2 in. × 2 in. × 1 in.

34. Rough pebble, decomposed. Chert (Carboniferous), 2 in. × 2 in. × $1\frac{1}{2}$ in.

35. Smoothed, worn and rounded. A cherty rock, magnesian limestone, 4 in. × 3 in. × 2 in.

36. Cubical, and angles slightly rounded. Porphyrite, 4 in. × 4 in. × 4 in.

37. Rounded and smooth, much decomposed. Tuff, 7 in. × 5 in. × 4 in.

38. Angular and smooth. Felstone, 5 in. × 4 in. × 3 in.

39. Smooth rolled, subangular pebble. Black chert. Carboniferous, $1\frac{1}{2}$ in. × 1 in. × 1 in.

40. Cubical and smooth. 'Porphyritic' ash. 10 in. × 8 in. × 4 in.

41. Subangular, faces smoothed. Felstone, 9 in. × 6 in. × 4 in.

42. Small pebble, smoothed, subangular. Tuff, $1\frac{1}{2}$ in. × 1 in. × $\frac{1}{2}$ in.

43. Rhomboidal, subangular. Magnesian limestone, 8 in. × 6 in. × 5 in.

More specimens of magnesian limestone than are named in this list have been found, together with numbers of boulders of a red sandstone differing from any local rock, and like some of the New Red Sandstones of Lancashire and Cheshire.

The probable sources of three-fourths of the erratics which have been identified are to the north-west.

Slate rocks and tuff, from Borrowdale volcanic series of the Lake districts.

Carb. limestone and chert, from North Lancashire or North-west Yorkshire.

New red sandstone, from North Lancashire.

Millstone grits and gannister series, from Pennine hills and borders, across South-west Yorkshire to Crosspool.

Several of the specimens were probably derived from the east lowlands of Scotland, while the magnesian limestones are from the north-east of England.

Midland Counties.—From Professor T. G. Bonney, M.A., F.R.S., the Committee has received the following report:—

Erratic blocks are so rare on or near the northern edge of Cannock Chase, in the vicinity of the Trent, that the following instances are worth recording.

In the immediate neighbourhood of Rugeley I only know of one erratic; as a rule one does not hesitate to refer all pebbles to the Bunter conglomerate, directly or indirectly. That formerly stood in an open part of a street on the south side of the town, where the name 'Crossley Stone' is still a record. Some years since it was broken up, and the fragments removed to the neighbourhood of a canal wharf on the opposite side of the town. There are now two fragments, partly buried in the ground: the larger measures 4 ft. 6 in. × 4 ft., and is at the thickest part 1 ft. 2 in.; the other piece is a little smaller. The first two dimensions, as far as I can remember, represent the area of the original stone. The rock is a compact grey felstone, a typical example of a boulder of the 'Arenig dispersion.'

In the village of Colton, about one mile from the Trent, and on its left bank, boulders appear to be more common. Four are used as guards at the angle of a little bridge near the church; one is rudely triangular, each side being about 2 ft. 6 in., and the thickness about 1 ft. 3 in.; a second is about 3 ft. × 1 ft. 9 in. × 1 ft. 6 in.; a third rather smaller. These are a grey granite, like that from Criffel. The fourth boulder is rather oval, its longest diameter being about 3 ft. This is a moderately coarse syenite, consisting of pinkish felspar and green hornblende, with a little quartz—I believe, a Scotch rock; these, of course, are not *in situ*, but cannot have been brought from far. Built into walls, used as steps, or lying about in or near the village, are several other boulders of smaller size, commonly not exceeding 1 ft. 6 in. in longest diameter. The grey granite (Criffel) is the commonest rock; but I noticed two of the 'Arenig' felstone, one also of a greenish-grey felspathic grit, some of the (not numerous) quartz grains being of a bluish colour—probably from Wales—and one (at the crossing of two roads in the village) a minutely crystalline syenite or hornblendic granite, reddish felspar being the predominant mineral. I have seen the rock before in collections of erratics. I believe it is Scotch, though I think there is a rock something like it in the Carrock Fell region. It is certainly of northern origin.

The following boulders in the Midland Counties are recorded on the authority of Mr. Horace Pearce, of Stourbridge:—

Boulder (10 ft. in circumference, 2 ft. × 10 in. in height) in parish of

Clent, Worcestershire, at junction of road from Stourbridge to Bromsgrove, with by-road to Clent Hills. Felstone. Another block of felstone is on the opposite side of the road.

Boulder (11 ft. 7 in. in circumference) just beyond the north-west corner of Highgate Common, Staffordshire, near a large Spanish chesnut-tree. Granite.

Group of boulders near Claverly, Shropshire, and between there and Bridgnorth, comprising blocks of granite and felsite.

Boulder (9 ft. 4 in. in circumference) near Waystone, Abbot's Castle Hill, in boundary road between Staffordshire and Shropshire. Felsite.

Boulder (5 ft. in circumference) on boundary road near Halfpenny Green, Salop. Vein quartz.

Group of boulders near Gospel Ash, Staffordshire, comprising blocks of hornblendic granite poor in quartz, and said by Professor Bonney to be indistinguishable from specimens from Buttermere, and compact felsite and mica syenite.

Shropshire.—The group of erratic blocks near Clun has been further examined by Mr. Luff, who reports that he has this year tracked the large Plinlimmon boulders lying in the Clun district eastwards from Black Hill over the Twitchen valley on to Clunbury Hill, and westwards to Beguildy, on the Radnorshire side of the Teme, *i.e.* for a distance of about $10\frac{1}{2}$ miles. Southwards they dot the country here and there as far as Llanvair Waterdine, about five miles distant. Smaller fragments lie in a pretty continuous stream right up to Kerry Hill in Montgomeryshire. None have as yet been found north of the Clun valley. Though they are most plentiful on the top of the ridge of hills south of Clun, they are by no means confined to high levels.

The highest boulder is upon Black Hill. It is a grit from Rhayader, 23 miles W.S.W., and has an elevation of something over 1,400 ft. Standing on Black Hill by this boulder, and looking westwards, the mountains of Radnorshire and Montgomeryshire are seen rising in transverse ridges across the line of sight, mass above mass in gradual stages, the hills in the near front being 1,200 to 1,400 ft. high; the Radnorshire Beacons, 1,796 ft.; Rhydd Hywell, 1,919 ft.; up to the Plinlimmon range itself, twenty to thirty miles distant.

At present there appears to be no intermixture on this horizon of erratics from any other direction but the west. Granite boulders occur on the north flank of the Longmynd, *i.e.* within about sixteen miles. The hills on the north of Clun, it may be noted, are not so high as those on the west. In addition to those recorded in the last report the following boulders have been observed:—

'The Fairy Stone,' on the south-west corner of Clunbury Hill, pebble grit from the neighbourhood of Rhayader. Size, 3 ft. × 2 ft. 3 in. × 2 ft. 6 in. Exact position, 52° 24′ 35″ N., 2° 55′ 20″ W. Subangular.

Llanvair Hill Boulder, 3 ft. 9 in. × 4 ft. 7 in. and 2 ft. deep. Subangular. Grit from district as above.

Burfield Flagstone, about half a mile west of the 'Great Boundary Stone' described last year, and, like it, from near Machynlleth. 7 ft. 9 in. long, 6 ft. broad; deeply buried in the ground, from which one end rises 2 ft. 6 in.

The Beguildy 'Stone,' 52° 24′ 10″ N., 3° 10′ 30″ W. Height above ground, 3 ft. 6 in.; breadth, 4 ft. 3 in.; thickness—very irregular—from

12 in. to 24 in. Thoroughly rounded at every angle. Many unsuccessful attempts have been made to remove this stone, for, standing in the midst of a field, it is an obstruction to agricultural operations. At a depth of 4 ft. it is said to spread out to a much greater thickness. It also is a Llandovery grit, and its parent rock is in the Rhayader district, though it is commonly believed to have travelled from a different direction; for the popular legend says the devil threw it from the Graig Don rocks, near Knighton, at Beguildy church, and as a proof the marks of his hand are still pointed out upon it. One of these marks is a bowl-like depression on its upper surface 12 in. diameter and 5 in. deep.

Leicestershire.—Mr. J. Plant continues his reports upon the Leicestershire groups of boulders:—

A. Isolated Boulders.

Hallaton, near Uppingham, Leicestershire, south-east.—On the roadside at Hare Pie Bank is a large erratic block, 7 ft. × 6 ft. × 3 ft. Fine striæ cover the upper surface. The block is said to have been moved some twenty yards, from an adjoining field, some fifty years ago. It was found lying in the upper boulder clay, which is very thick over this district (in some places over 80 ft. deep), and contains boulders of all sizes, including very large flints. Many of the boulders are covered with scratches. Height above the sea between 500 and 550 ft.

The erratic looks like a calcareous sandstone of the marlstone rock, which is found below the drift in the immediate neighbourhood. No outcrop of this rock occurs in the neighbourhood nearer than Tilton, some six miles to the north-west.[1]

Numbers of erratics, but of smaller dimensions, are found in the village itself, forming the foundations of old farm-houses, walls, &c. Many of these are millstone grit, mountain limestone, and sandstone from the coal measures.

Road from Loughborough to Ashby, Leicestershire.—A large erratic, size 3 ft. × 3 ft. × 2 ft.; not known to have been moved. It is of millstone grit, and must have come at least thirty miles' distance from the north. No striæ are visible. Height above the sea, about 250 feet.

B. Groups of Boulders.

Saxe-Coburg Street, Leicester.— Two more large boulders have been uncovered here in excavating for the foundations of houses; size, each about 3 ft. × 2 ft. 6 in. × 1 ft. 10 in. They are of Mount Sorrel granite, distant about seven miles north. They are rounded and subangular. No striæ seen. They were found lying about 6 ft. deep in the boulder clay. Height above sea, about 260 ft.

[1] A curious annual custom is observed at Hare Pie Bank, which may be connected with the boundary of the parish. A large meat pie is made, and is placed, with a wooden bottle, in a large hole, in the presence of representatives from certain villages. The meat pie is distributed, but a struggle takes place for possession of the wooden bottle with the representatives from the adjoining villages. This confers upon the village obtaining possession of the bottle certain privileges for the year. Whether this remarkable ceremony has any connection with the large erratic as marking the boundary could not be ascertained.

Leicester Forest and Kirby Muxloe.—On the road from Leicester to Hinckley, about 4½ miles from the former place, is a large boulder in an orchard, showing only a small piece about 2 ft. square. On being uncovered it was found to be 6 ft. × 4 ft. × 4 ft. 6 in. This block has never been moved, and is lying in the drift; the longer axis is in the direction of the north. No striæ are visible. It is of the coarse-grained Markfield syenite, distant about four miles north-west. The block is angular, some angles as sharp as if recently quarried.

In an adjoining field on the west side of this orchard are two large blocks; size, each about 3 ft. × 2 ft. × 2 ft. each. Some edges are rounded, others very sharp and angular. They are of Markfield syenite, distant about four miles. They are said to have been moved about four yards from a depression in the ground. No striæ are seen.

Not many yards to the north of the above spot is a group of four blocks, two of them about 4 ft. × 2 ft. 6 in. × 2 ft.; the others are irregular cubes of about 2 feet.

A further group occurs not many yards from this group; average size, 3 ft. × 2 ft. 6 in. × 2 ft. These are lying on the surface. Both these groups are of Markfield syenite, distant about four miles.

The mean height at which all these boulders are found may be taken at about 290 to 300 ft.

On the turnpike road from Leicester to Hinckley, near the fifth milestone, is a group of three blocks, the largest 3 ft. × 2 ft. × 2 ft. This group is of Markfield syenite, distant about 3½ miles north-west. N.B. In these irregular-shaped blocks, the longest side each way is always measured.

On the footpath from the Hinckley road to Kirby Muxloe, is a large erratic buried in the drift, the top of which only is exposed. Size 4 ft. 6 in. × 3 ft.; being buried in the drift the depth is not known.

A recent bench-mark has been carved on this stone, the height of which can be given when the new Ordnance map of this district is published.

This block is also of Markfield syenite, distant about three miles north-west. No striæ are seen.

Near a farm-yard in the next field to this bench-marked block, is a group of three blocks, one 3 ft. × 3 ft. 6 in. × 2 ft.; the others smaller. These are also of Markfield syenite.

Kirby Muxloe.—In the village of Kirby Muxloe is a group of seven blocks. Average size 3 ft. × 2 ft. 6 in. × 2 ft. They are of Markfield syenite. No striæ observed.

In another part of the village is a group of four blocks, from the same locality. Size 2 ft. × 2 ft. × 1 ft.

I counted more than a hundred blocks, of sizes varying from 2 ft. 6 in. to 1 ft., built into old walls and foundations of houses, which must formerly have been lying in the drift about the village.

In a cottage garden in the village is an isolated block; size 4 ft. × 2 ft. × 2 ft., of Markfield syenite. There are three distinct grooves in this block.

In the Manor House garden is another block, 4 ft. × 4 ft., partly buried in the ground, but estimated to be 5 ft. deep. It is of Markfield syenite.

Numerous other boulders lie scattered in the fields, with only portions exposed, of the same character of rock.

One mile from Kirby Muxloe, on the road to Newton Unthank, is an isolated block by the road-side. Size 4 ft. × 3 ft. × 2 ft. 6 in. This fine block, with sharp angular sides, has never been known to have been moved, and is of the white variety of syenite from Markfield.

The whole of these isolated and groups of boulders, described under this head, are spread over an area of about two miles long by half a mile wide, the longer direction being south-east of Markfield, from whence they are supposed to have been derived. Some are entirely exposed, others are partly buried in the drift, which lies very thick in the valleys, but on some of the uplands is not many inches deep. From observations made some miles further to the south-east, there would appear to be a continuous line of these erratics from the syenitic rocks round Markfield and Groby. There must still be many thousands buried in the drift, as in any comparatively shallow excavation made over this area, erratic blocks are sure to be met with.

Hertfordshire.—Mr. H. G. Fordham contributes records of erratics and notes referring to several parishes in the north of Hertfordshire, in continuation of his former Report on that district.

Kelshall.—The village of Kelshall is situated about 500 ft. above sea-level on the ridge of the chalk outcrop bounding the watershed of the Thames on the north, and dividing it from that of the Cam or Rhee. This ridge, with the country to the south within the watershed of the Thames, is covered with boulder clay; on the north, in the valley of the Rhee, and to the north-west, in the district draining into the Ivel, some of the more prominent hills and transverse ridges are capped with patches of boulder clay (as at Ashwell, *Report*, 1881, p. 207 *et seq.*, and at Bygrave). The two following boulders, when they were examined in September 1880, were lying together in a grass field, near the end of a cart-shed, on the north side of the road leading into the village from the west, and about 100 yards north of the church, upon the ridge already referred to, just on the dividing line or water-parting between the Thames and Rhee.

1. Smoothed, with five flat, or nearly flat, facets on the top and sides as it now stands. Mr. J. Vincent Elsden, F.G.S., describes the material from a small specimen as:—'Very much decomposed throughout. The interior shows traces of an original dark crystalline rock, containing much magnetite which has weathered reddish-brown. Felspar crystals (probably plagioclase) are distinguishable. Probably dolerite.' 3 ft. 4 in. × 2 ft. 9 in. × 2 ft.

2. Roughly rhomboidal, much worn, and the upper surfaces, and to some extent the sides, furrowed by atmospheric action. Compact limestone: mountain limestone. 2 ft. 7 in. × 2 ft. 6 in. × 2 ft.

Bygrave.—Bygrave adjoins Ashwell on the south-west. The church and a few houses and cottages, hardly amounting to a village, stand on the summit of a low isolated hill, within the area draining into the Ivel. The whole of the higher part of this hill is covered with boulder clay, its highest elevation being about 320 ft. above sea-level (bench-mark on church 314 ft.). The only boulder of any size lies on the top of the hill, on the side of the road, about 70 yards west of the church:—

Yellowish, compact sandstone. About 3 ft. × 2 ft. × 2 ft.

Hitchin.—The town of Hitchin, on the Hiz, a tributary of the Ivel, lies at an elevation of about 220 ft. above the sea-level (bench-mark on church 216 ft.). On the west and north-west of the town are hills capped by thick beds of glacial gravel. From one of these, in ancient workings for gravel, the boulders now lying near in the stable-yard at The Hermitage have, no doubt, been obtained. They now lie about 212 ft. above sea-level, but if derived from the adjacent hill they may be estimated to have been originally deposited at a level perhaps 50 ft. higher. In the large excavations for chalk adjoining the Hitchin Railway Station, a good section of sand and gravel is exposed above the chalk. Large boulders have been obtained from this gravel, and some of these now lying on the floor of the pit are described below. Their original elevation above sea-level may be estimated at 240 to 280 ft.

Boulders lying in the stable yard, The Hermitage.

1. Long, irregular, rounded, in shape fairly rectangular; top irregular, but in general outline smooth and flat; one end flat, the other uneven; whole surface slightly eroded. It is used as a mounting-block. Yellow sandy limestone, containing numerous large *belemnites*, and some *ostreæ* or *gryphææ* (?). Most probably lias marlstone. 5 ft. × 2 ft. 5 in. × 2 ft.

2. Smooth, slightly pyramidal in shape. Hard, compact sandstone, weathering iron-red. 2 ft. 7 in. × 1 ft. 3 in. × 1 ft. 1½ in.

3. Rounded, smoothed, and upper surface scratched (?). Compact limestone, containing fragmentary fossils—? *spiriferæ*: probably carboniferous or silurian limestone. 1 ft. 11 in. × 1 ft. 7 in. × 1 ft. 1 in.

4. Irregular, smoothed. Same material as 2. 1 ft. 3 in. × 1 ft. × 9 in.

In addition to the above, about 200 smaller boulders, varying from 6 in. long up to nearly 1 ft. and 1 ft. 6 in., are used to mark the margin of the road. There is also amongst them a block of Hertfordshire Pudding Stone, about 2 ft. × 1 ft. 9 in. × 6 in., angular and apparently unworn.

Boulders lying in chalk pit adjoining railway station.

5. Rhomboidal, surface smoothed and angles rounded. Faces, particularly one of the sides, flat. Brown, compact sandstone. 4 ft. × 2 ft. × 1 ft. 10 in.

6. Rounded and worn, one end broken off. Hard, grey, crystalline limestone. 2 ft. 2 in. × 1 ft. 5 in. × 1 ft. 3 in.

7. Very much worn and rounded, one side nearly flat. Hard, dark, crystalline limestone. 2 ft. 7 in. × 1 ft. × ?

8. Irregular, but little worn fragment. Compact, veined, light-brown sandstone. About 1 ft. × 1 ft. 6 in. × 6 in.

9. Irregularly shaped, worn and rounded, with all angles rounded and the surfaces smoothed, hollowed or rounded; no scratches, upper surface nearly flat and decomposed, otherwise very hard. Yellowish-brown, somewhat crystalline limestone, containing fragments of fossils (?). Probably inferior oolite or lias marlstone. 5 ft. 2 in. × 3 ft. 2½ in. × 2 ft. 6 in.

10. Irregularly shaped, somewhat worn and rounded; some parts of surface much worn, very hard, and rather inclined to split on lines of

bedding. Apparently same material as 9. 2 ft. 4 in. × 1 ft. 8 in. × 1 ft. 5 in.

11. Irregularly cuboidal, but little worn, sections of fossils in surface (? gryphææ). Material similar to 9 and 10. 1 ft. × 10 in. × 7 in.

12. Rounded slab, surface easily scratched, shallow, rough grooving on one side, probably of recent origin. Light yellow concretionary mass, fracture conchoidal. Possibly from the Oxford clay. 1 ft. 8 in. × 1 ft. 3 in. × 5 in.

13. Flattish, rounded. Hard, dark blue basalt, 1 ft. 3 in. × 11 in. × 6 in.

14. Broken fragment, rounded and worn. Hard, dark-brown, crystalline limestone. 1 ft. × 10 in. × 6 in.

15. Angular fragment. Crystalline, fossiliferous, brownish-yellow limestone, with cavities lined with small calcite crystals; small *pecten* and other fragmentary fossils. Oolite, probably. 9 in. × 9 in. × $5\frac{1}{2}$ in.

16. Rounded, broken end of what appears to have been originally a flat, oval boulder. Iron-stained, reddish-brown limestone, contained numerous fossils. Section across both valves of a *gryphœa arcuata* on upper surface. Lias. 1 ft. 1 in. × 9 in. × $4\frac{1}{2}$ in.

17. Flat, but little worn. Same material as 9, 10, and 11. Contains small *pecten*. 10 in. × $9\frac{1}{2}$ in. × $4\frac{1}{2}$ in.

18. Irregular surface, worn. Hard crystalline, shelly limestone. Much like Purbeck marble in character, but probably an older rock. $11\frac{1}{2}$ in. × 8 in. × $4\frac{1}{2}$ in.

19. Broken concretion, similar to 12.

20. Subangular, polished and scratched on all its faces, angles rounded. Short scratches and little grooves on all parts of the surface, on concaved as well as convexed faces. Hard, dark, crystalline limestone. $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in. × $4\frac{1}{2}$ in.

21. Flat-topped, irregularly-shaped slab. Top and two of the sides decomposed and soft from atmospheric action, perhaps also somewhat broken. The other sides and a small part of the upper surface hard, smooth and worn. Crystalline, fossiliferous limestone. 2 ft. 6 in. × 1 ft. 8 in. × 1 ft. 2 in.

22. Regular rhomboidal, with uneven but worn and smoothed surface, polished in places, and with scratches well marked in several places. Hard, compact, crystalline limestone. 1 ft. 1 in. × $9\frac{1}{2}$ in. × 6 in.

23. Long, irregular-shaped broken fragment, one side only worn. Hard, dark, crystalline limestone. 1 ft. 2 in. × 8 in. × 6 in.

24. Rectangular, edges rounded, and surface smoothed. 2 ft. × 1 ft. 6 in. × 10 in.

25. Broken, rounded fragment. Grey, fossiliferous, crystalline limestone. 11 in. × 8 in. × $4\frac{1}{2}$ in.

26. Roughly cuboidal in shape, slightly worn. 8 in. × 8 in. × $6\frac{1}{2}$ in.

27. Angles worn, sides flat. Iron-stained sandstone. 1 ft. 10 in. × 10 in. × 7 in.

28. Irregularly shaped, broken piece, not much smoothed, but on one side scratched deeply. 1 ft. 9 in. × 1 ft. 2 in. × 7 in.

29. Roughly rectangular slab, angles rounded, sides flat. 1 ft. 6 in. × 1 ft. 4 in. × 9 in.

30. Long slab, subangular, scratched and smoothed. 1 ft. 9 in. × 1 ft. × 8 in.

31. Subangular, worn. Sandstone. 1 ft. 1 in. × 1 ft. × 11 in.
32. Rounded and worn. Iron-stained, coarse-grained sandstone. 1 ft. × 1 ft. × in.

The evidence at present collected goes to show that in the district referred to the erratics are generally distributed over the country without reference to its elevation, and reaching a height of more than 500 ft. above sea-level—the highest hills being capped with boulder clay containing large boulders. It is also clear that as a rule the boulders of all sizes, up to the largest known, are derived from the oolites and lias, probably of the Midland Counties, but that in addition there is a fair sprinkling of older rocks from further north. Carboniferous limestone and millstone grit supply here and there a boulder of large size. Dark blue basalt is also not uncommon, and is occasionally found in blocks of a fair size. Granites are rare—two specimens only having been noted.

NOTE.—*The large boulder at Royston, referred to in the 5th Report, 1877, p. 84, has been more fully described in the 'Transactions of the Watford Nat. Hist. Society,' vol. ii. p.* 249.

Anglesey.—Professor Bonney, F.R.S., sends the following report:—

A visit to the district south-west of Ty Croes enables me to add to the number of picrite boulders already recorded ('Quart. Jour. Geol. Soc.' vol. xxxvii. p. 137, and vol. xxxix. p. 254). From Ty Croes station a road runs south-west. Taking first turn to the right, after crossing a field, I found in a field to right of the lane a fragment of a boulder (measuring by estimate about 2 ft. × $1\frac{1}{2}$ ft. × $1\frac{1}{4}$ ft. of picrite of the ordinary type described in the above papers. About half-way between this spot and a farm-house seven fragments of a large boulder are built into the wall by the roadside: three of these are quite 2 ft. in diameter, the rest smaller. Outside the buildings of a second farm along the same lane are two fragments of picrite, the larger about $3\frac{1}{2}$ ft. × $2\frac{1}{2}$ ft. × $1\frac{1}{2}$ ft.; the longest diameter of the other being about $2\frac{1}{2}$ ft. On the sandy shore at Porth Noble, some distance to the north of the boulder described in the second of the above papers, lies a large subangular boulder of the usual picrite, measuring about 4 ft. × 4 ft. × 2 ft. On my return by the Frondwl specimen I found fragments of another picrite boulder about 80 yards nearer the church, built into the base of the wall (vegetation will generally conceal these). On looking again at the boulders in the Cromlech Barclodiad-y-gawras I felt some doubt as to the correctness of my former identification of picrite ('Loc. Cit.' vol. xxxix. p. 254), but without injuring the stones it is difficult to be sure. It is, however, evident that, at any rate in this part of Anglesey, boulders of hornblende-picrite are rather common. I may add that during a stay of a few days at Penmaenmawr I did not see a single picrite boulder, though erratics are abundant, as there is boulder drift on the lower ground.

Ninth Report of the Committee, consisting of Professor E. HULL, Dr. H. W. CROSSKEY, Captain DOUGLAS GALTON, Professors G. A. LEBOUR *and* J. PRESTWICH, *and* Messrs. JAMES GLAISHER, H. MARTEN, E. B. MARTEN, G. H. MORTON, W. PENGELLY, JAMES PLANT, JAMES PARKER, I. ROBERTS, THOS. S. STOOKE, G. J. SYMONS, W. TOPLEY, E. WETHERED, W. WHITAKER, *and* C. E. DE RANCE (*Secretary*) *appointed for the purpose of investigating the Circulation of Underground Waters in the Permeable Formations of England, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations. Drawn up by* C. E. DE RANCE.

TEN years having elapsed since your Committee was appointed at Belfast, they think this a fitting opportunity to review the results so far obtained, and to point out where they consider additional information is still required, in the hope that they may receive assistance in their investigations from the various local societies or from individuals who may be disposed to aid in the work.

Composition of the Committee.—The Chairman of the Committee, Professor Hull, F.R.S., and the Secretary, Mr. De Rance, F.G.S., were appointed in 1874; the nine reports have been drawn up by the latter. Of the original Committee, Professor Prestwich, F.R.S., Messrs. Morton, J. Plant, W. Whitaker, and the Rev. Dr. Crosskey also still serve. The Committee have lost by death Professor Harkness, F.R.S., Mr. Binney, F.R.S., Mr. Charles Moore, F.G.S., and Mr. W. Molyneux, all of whom have rendered important assistance, as have the following, who have retired from the Committee: Messrs. Mellard Reade, C.E., Tylden Wright, H. H. Howell, Fox-Strangways, and Lowe, F.R.S. General assistance has been given by the following, who have since retired from the Committee: Sir Frederick Bramwell, F.R.S., the Rev. W. S. Symons, and Mr. R. W. Mylne, F.R.S.

The members of the Committee who took charge of districts and have carried out the heavy work of the inquiry, were in the Midlands, Mr. James Plant, Mr. W. Molyneux, and Mr. H. Marten; in the south-west of England, Messrs. Pengelly, Moore, and Stooke (the latter has obtained also much information in Shropshire and Cheshire); in Lancashire the work has been done by Messrs. Binney, Morton, and De Rance, supplemented by very valuable special reports by Messrs. Mellard Reade and I. Roberts; in Gloucestershire Mr. Wethered has done good work, and contributed a report of great value on the quantity of water held by rocks of various ages; in the north-east of England the work has been done by Professors Green and Lebour, and Messrs. Howell and Fox-Strangways.

The work entrusted to your Committee was twofold—first, to inquire into the circulation of underground waters in permeable formations; secondly, to ascertain the quantity and quality of the water supplied to towns and districts from these formations. The information obtained occupies nine reports; the eight already published fill up no less than 163 pages of the annual volume of the Association, and contain a record of upwards of 500 wells and borings.

Your Committee believe that the publication of these results, by

directing public opinion to the value of such supplies, and by the preservation of the records of those carried out, has given an impetus to water of this class being generally adopted for domestic consumption in districts where gravitation supplies are unsuitable or unattainable.

As regards the first head of inquiry—the circulation of underground waters—much remains to be learnt, especially as to the influence of variation of barometrical pressure on the volume of springs. Independent investigation is now being carried on by Mr. Baldwin Latham, but it is exceedingly desirable that numerous observations should be taken in different classes of rocks, the quantity of water a rock is capable of holding being no measure of the quantity of water it is capable of yielding. The difference of the period of time in which two rocks will absorb, and give off by gravity, the same quantity of water is governed by the difference of their chemical composition.

The chemical composition of two rocks being identical, their facility of discharge of water is in direct relation, to the amount by which they are traversed by planes of joints and fissures, and the extent these may run parallel or at right angles to the valleys which cut into and expose the water-bearing beds.

The proportion of the annual rainfall that is absorbed by different classes of rocks is a subject that requires further examination. The quantity is largely regulated by the quantity stored from previous years. After a succession of dry years the permanent water-level is reduced to minimum figures, and the water gradient becomes nearly flat and springs cease to flow. The first heavy rains will be nearly wholly absorbed, until the maximum water-gradient is reached and the rocks are stored with the largest amount of water they can hold. After they are once charged, all excess of rainfall runs off in floods, and the amount absorbed is practically *nil*. Spread over the twelve months, the annual amount absorbed is probably never more than 15 inches, and the average ranges from 5 inches in chalk countries to 10 inches in new red sandstone areas. In millstone grit districts about 8 inches are absorbed, but the permeable beds are thin, and the water is thrown off again in numerous springs, as a rule in the same drainage basin, giving permanence to the dry-weather flow of the streams traversing them. Except in *Waterworks drainage areas* but few observations exist as to the actual volumes run off daily by the rivers of this country, and data on this subject are much required, as well as a permanent record of the height to which floods rise in the various river-basins.

Further observations are required as to the action of faults in acting as ducts, along the face of which water is constantly passing, and barriers separating districts into distinct drainage areas. The facts so far obtained point to faults traversing thick permeable sandstone and limestone, having these formations on both sides of the dislocation, as offering no obstacle to the free passage of waters, which, even if locally obstructed by the hardened face or slickenside jointing of the fault, invariably finds its way through cracks extending across the width of the fault. In faults traversing thick shales and clays of any age, the fissure, be it wide or narrow, always appears to have been filled with the impermeable material forming the sides, and in some cases, when porous rocks have been immediately overlain by impermeable material since denuded, the fissure of the fault has been filled from above at a time when the fault had an upward prolongation, destroyed with the above-mentioned denuded material.

The daily registration of the heights of the streams might easily be made on gauges, painted on the county bridges, but the organisation necessary to carry this out is entirely beyond the scope of the British Association, and should be carried out at the national charge, being of the highest importance to the country.

The determination of the number of cubic feet of water, carried down at selected points on the English rivers, particularising whether it represents *dry-weather*, *average*, or *flood-flow*, would be of very high value, and might well be undertaken by the Association. Such observations, stating the run off per square mile of drainage area and the geological character of the area drained, would have more than a local value.

Permeable rocks below the permanent water-level of a district may be regarded as a reservoir of which the cubic content is limited by the size of the spaces between the grains, and the width of the fissures and cracks by which the rock may be traversed. The quantity of water such rocks are capable of storing, has had much light thrown upon it by the investigations of Mr. Wethered, published in the fourth appendix to the eighth report.

The following figures give an abstract of his results as to some of the most typical rocks examined by him:—

Rock	Locality	Gallons of water absorbed per square inch of rock	
		Cubic foot of rock	3 feet thick
Old Red Sandstone . . .	Bristol . . .	·642	53,754,000
Old Red Flags	Caithness . .	·086	7,254,000
Old Red Conglomerate . .	Gloucestershire .	1·172	98,000,000
Carboniferous Limestone .	Clifton . . .	·010	887,000
" " .	" . . .	·049	4,122,000
Millstone Grit	Bristol . . .	·058	4,853,000
" "	South Wales (very coarse) .	·355	28,747,000
" "	Forest of Dean .	1·119	93,625,000
Pennant Grit	Bristol . . .	—	—
Coal Measure Grit (Pennant type)	" . . .	·112	9,446,000
Coal Measure Grit (Millstone Grit type) . . .	" . . .	·273	22,910,000
Bunter Sandstone . . .	Heidelberg . .	·838	70,889,000
Magnesian Conglomerate .	Clifton . . .	·133	11,168,000
" Limestone . .	" . . .	1·044	87,363,000
Great Oolite (hard) . . .	Bath . . .	1·473	123,268,000
" " (soft) . . .	" . . .	2·157	180,415,000
Inferior Oolite (Building stone)	Cheltenham . .	1·496	125,147,000
" " (Pisolitic) .	" . . .	·146	12,264,000

Mr. Wethered draws attention to the chemical analysis of the top-bed of the filter-beds of the Chelsea Waterworks, which corresponds with the analysis of the Millstone Grit and of Pennant Grit. In both cases there is nothing in the chemical composition of the filtering medium which can oxidise the organic impurities of water passing through. The oxidation in the filter is effected by air between the grains of sand, and in the rocks by air collected in the interstices; and he points out that with water yielded through fissures and joints in the strata, as is the case with the

water derived from the Carboniferous Limestone, which does not percolate, it is a question whether the purifying process would be always satisfactory.

Appendix I.—Information obtained in 1882–3.

By C. E. De Rance.

Information collected by C. E. De Rance, F.G.S.

Underground Water in the Oolites at Birdlip, near Gloucester.—The escarpment overhanging the Vale of the Severn, near Gloucester, consists of the following sequence of oolitic rocks at Leckhampton Hill :—

Great Oolite	—
Fuller's Earth	20 feet.
Inferior Oolite	264 „
Lias Sands	28 „
Upper Lias Clay	202 „

The Great Oolite and the upper part of the Fuller is permeable, and the water is supported by the very impermeable layer occurring at the base of the Fuller's Earth. Water traverses the Inferior Oolite freely, especially through the numerous joint planes by which it is traversed, and descends into the Lias Sands, which constitute an important underground reservoir, supported by the lias clays, which throw out numerous springs. The dip of all the beds is eastwards, or from the escarpment into the hill; for the dip of the rocks forming the actual scarp is directly modified by a slip caused by the drag of the hill, the dip being toward the plain beneath. This has an important influence on the direction of the water-flow, the position of which has been determined with much accuracy at Birdlip in a series of borings made by the Gloucester Corporation Water-works, for the journals of which I have to thank Mr. T. H. Fryer, Town Clerk of Gloucester.

Bore holes	Surface level	Water level	Level at bottom of bore-hole	Difference of water-level		Remarks
No. 3	222·57	177·57	147·07			Rose 9 feet, or
No. 4	437·54	257·68	133·54	80·11 ↑		Rose 10 in 24 hours.
No. 2	425·22	249·22	150·72	8·46	↓	Rose 10 feet in 1 hour.
No. 1	395·93	235·93	92·43	13·29	21·75	Rose 12 feet in 1 hour. Rose to 35 feet.

The dip between No. 1 and No. 2 is 1 in 26.

These oolitic rocks are traversed by numerous small faults, ranging about W. 10 N., mostly with downthrows to the north. It does not appear to be certain whether they act as barriers or not to the passage of underground waters.

South-west Lancashire.—A boring has recently been made at Hall Wood, about six miles east of Liverpool, by Mr. Timmins, of Runcorn, for the Cheshire Lines Railway Committee, in search of water. The boring has reached a depth of 414 feet, the whole of which was carried through stiff reddish-brown clays, samples of which have been kindly forwarded by Mr. A. Timmins, Stud. Inst. C.E., the upper portion of

which appears to be referable to the boulder clay, but as to the age of the lower part there appears to be much uncertainty. No Glacial Clay is known to occur in the district at so great a depth. The Keuper Marls cannot be present unless they are let in by unknown trough faults, and if present can only occupy a very small area; while the Permian Marls, and the Clay beds of the Upper Coal measures, do not attain in this area the great thickness observable in this boring; nor does the surface evidence afforded by the surrounding country support the view of their being referable to either of those formations. In the hope that some light might be thrown on the problem by microscopical examination, I submitted the samples to Mr. J. A. Phillips, F.R.S., who has kindly examined them, and reports as follows:—

'The plastic red specimen (395 feet) is a fine clay, strongly coloured by oxide of iron, and apparently contains patches of greyish *boulder clay*. After being attacked by hydrochloric acid it became perfectly colourless, and this white residue consists of clay containing fragments of angular quartz, with a substance which is probably kaolinite, resulting from the decomposition of felspars.

'The coarser sample (Hall Wood, 414 feet) is like the former, but with a larger proportion of angular quartz, in fragments varying from $\frac{1}{1000}$ to $\frac{1}{150}$ inch in diameter. The clay does not appear to contain any particle of boulder clay.'

Surrey.—A very interesting boring is now going on at Richmond; it has penetrated the chalk and greensand, and has reached beds of red marl and hard red sandstone, with partings of pyrites, at 1,266 feet, specimens of which have been kindly forwarded by Messrs. Mather and Platt, of Salford Ironworks.

Information collected by Mr. Fox-Strangways, F.G.S.

1. At Irton, near Scarborough. **1a.** Finished August 1882. **2.** 94 feet. **3.** 70 feet, 10 feet diameter; 28 feet, 25 inches diameter; 152 feet, 20 inches diameter; 189½ feet, 12 inches diameter: total depth 439½ feet. **3a.** None. **4. 4a. 5.** Flows out at the surface at the rate of about 1¼ million gallons per 24 hours. **6.** The level does not vary, but the quantity increases after heavy rain. **7.** See previous answers. **8.** Analysis not made since the deep boring completed.

	ft.	in.
9. Clay and Soil	2	3
Gravel	17	0
Clay	2	9
Sand and Gravel	0	9
Marl	1	0
Sand and Gravel	2	9
Marl	8	6
Sand with Boulders	4	9
Gravel with Boulders	3	0
Warp	5	9
Brown Marl	5	3
Kimmeridge Clay	44	3
Rock	21	0
Very hard rock	25	6
Light compact rock	9	0
Hard rock	34	6
Dark-coloured hard rock	9	0
Open rock with hard bands	19	0
Hard rock	94	0
Soft or shaly rock	8	0
Hard rock	86	0
Rock mixed with tough bind	4	6
Close rock mixed with shale and sand	14	6
Blue clayey shale	16	6
Total depth	439	6

10. Yes. **11.** Yes. **12.** No. **13.** No. **14.** No. **15.** No.

Information collected by C. E. De Rance, from Mr. T. W. Shore.

1. Southampton artesian well at the S.W.R. terminus. **1a.** 1840. **3.** 64 feet to bottom of shaft. From the surface to the bottom of the bore-hole 220 feet.

	ft.	in.
9. New-made soil of mud with shingly gravel	8	0
Whitish clay and stones	2	0
Whitish clay, Gravel with clay, Yellow gravel	5	0
Green sand with water	5	0
Blue sand with *Venericardia* and *Turritella*	10	0
Blue sand like indigo	5	0
Blue sand	5	0
Slate-coloured sand	5	0
Bluish green sand with shells and water	10	0
Slate-coloured clay	5	0
Ditto with sand	4	0
Blue clay	6	0
Dark blue clay	10	0
Ditto with sand	2	0
Bluish sand with water	10	0
Clay with sand	35	0
Bluish sand with water	3	0
Black sand with water	2	0
Green sand with water	5	0
Blue clay with sand	10	0
Light bluish clay with sand	23	0
Light blue clay with little sand	5	0
Blue clay	2	6
Dark blue sand	2	6
Dark blue coarse sand with water	2	0
Coarse white sand with water	38	0
	220	0

Information given by Mr. T. W. Shore.

1. Southampton Docks artesian well. **3.** 63 feet to bottom of shaft; 374 feet from the surface to the bottom of the bore-hole; bore-hole 9 inches in diameter.

	ft.	in.
9. From surface?	30	0
Blue clay	10	0
Sand	10	0
?	58	0
Very hard blue clay	27	0
Dark green sand	5	0
Fine whitish running sand, with water	16	0
A mass of stone, ?	28	0
Light brownish clay, with sand, with occasional fragments of stone	11	0
Ditto, bluish	5	0
Hard blue clay, with very slight mixture of sand	15	0
Ditto, with broken shells	1	0
Hard lead-coloured clay, with very slight mixture of sand	34	0
Hard blue clay, with a slight mixture of sand	5	0
Hard bluish clay, without sand	5	0
Hard lead-coloured clay, with pyrites	5	0
Very hard, dense, lead-coloured clay	5	0
Hard clay, with pyrites	2	0
Hard dense clay, with nodular fragments	4	0

	ft.	in.
Hard clay	24	0
Layer of stone	0	6
Dense hard clay	12	6
Fine dense sand	3	0
Black rolled pebbles	2	0
Fine hard sand, with slight mixture of clay	3	0
Rolled black pebbles	1	0
Hard light-coloured sand	9	0
Sandy clay	7	0
Hard sand, with clay	3	0
Clay with sand	9	0
Clay	3	0
Sandy clay	2	0
Clay without sand	19	0
	374	0

Information collected by C. E. De Rance, from Messrs. Le Grand and Sutcliff, 100 *Bunhill Row, London, E.C.*

NATURE OF STRATA BORED THROUGH AT MELTON MOWBRAY.

Feet		Nature of Strata
2	1 to 2	Soil.
6	3 „ 8	Loamy sandy gravel.
2	9 „ 10	Yellow clay and sand.
1	11	Yellow clay.
3	12 to 14	Sandy gravel, with water.
23	15 „ 37	Blue clay and stone.
26	38 „ 63	Blue clay.
36	64 „ 99	Blue shale and stone.
168	100 „ 267	Blue lias clay and stone.
17	268 „ 284	Dark shaly clay and stone.
24	285 „ 308	Grey marl and stone.
61	309 „ 369	Red marl and gypsum.
1	370	Grey keuper sandstone.
3	371 to 373	Grey marl and gypsum.
35	374 „ 408	Red marl and gypsum.
1	409	Grey sandy marl and gypsum.
3	410 to 412	Red marl and gypsum.
1	413	Red sandstone.
4	414 to 417	Red marl and gypsum.
1	418	Red sandstone.
1	419	Red marl.
6	423 to 425	Grey sandstone, red marl, and gypsum.
50	426 „ 475	Red marl and gypsum
1	476	Grey sandstone.
24	477 to 500	Shaly red marl, sandstone, and gypsum.
14	501 „ 514	Red marl stone, grey sandstone, and gypsum.
4	515 „ 518	Grey sandstone.
11	519 „ 529	Red marl stone, grey sandstone, and gypsum.
1	530	Grey sandstone.
1	531	Red marl stone.
1	532	Grey sandstone.
532	532	

Information collected by Mr. James Plant, F.G.S., from the Local Board, Melton Mowbray.

1. Scalford Road, near Melton Mowbray, Leicestershire. **1a.** Boring commenced 1882; finished March 1883. **2.** About 250 feet. **3.** Depth 556 feet; diameter about 4 inches. **4.** No pumping, but water stands at 120 feet from the surface. **6.** Not observed. **8.** No analysis yet made.

	Depth of rocks Feet	Total depth Feet
9. Brown drift clay with large boulders	104	104
Brown sandy drift clay	45	149
Lower lias clay with thin bands of limestone	212	361
Rhætic	26	387
Keuper red marl with gypsum bands	130	517
Grey mottled sandstone	40	557

It is supposed this latter is the Upper Keuper sandstone, and it proves the existence of the Triassic rocks five miles further to the east than the known boundary in this county. **9a.** Several gypsum bands yielded water as well as the sandstone. **12.** A large fault distant about two miles to the N., bringing up the middle beds of the lias. This fault runs due E. and W., and is about thirty miles long. **14.** None known. **16.** Further operations are contemplated.

Information collected by Mr. James Plant from the Local Board, Hinckley, Leicestershire.

1. Hinckley Wharf. **1a.** Boring of 10 inches diameter; commenced November 1881. **2.** 313 feet.

3.

Depth of well	12	feet.
„ 10-inch bore	150	„
„ 7 „ „	314	„
„ $6\frac{1}{4}$ „ „	278	„
Total	754	„

4. The mean height at which the water stands in the bore-hole is 654 feet. **5.** Many thousands of gallons have been pumped out while testing the water, and the supply always rises to within 70 feet of the surface. **7.** Water-level is above the bed of the river Anker, distant about two miles S.W. of the bore-hole. **8.** Several analyses have been made by different analysts. The following is the average:—

In 100,000 parts there are—

Lime	67·31
Soda	202·50
Magnesia	19·00
Sulphuric acid	295·60
Carbonic acid	16·67
Silicic acid	2·00
Chlorine	61·70
Total	664·78

The above constituents are considered to be combined in the water as follows:—

Sodium chloride	101·67
Sodium sulphate	340·39
Calcium sulphate	163·47
Magnesium sulphate	11·50
Magnesium carbonate	31·85
Silicic acid	2·00
	650·88
Add oxygen equal to chlorine	13·90
Total	664·78

The specific gravity of the water (1·0060) is very great. The water is quite clear and limpid to the eye, and has a brackish taste, but contains not the slightest organic impurity. By continuous pumping for some weeks the solids in solution have been reduced from 650 (parts in 100,000 parts) to 465, and it is fully expected that further pumping will greatly reduce this quantity. **9.** See Report for 1882 for description of rocks down to 705 feet 2 inches.

	Depth of rocks ft.	in.	Total depth ft.	in.
Mottled sandstone, red and grey	12	6	717	8
Red sandstone, coarse	7	10	725	6
Grey sandstone	15	0	740	6
Grey sandstone, conglomerate, pebbles size of peas	7	6	748	0
Red sandstone, fine-grained	6	0	754	0

9*a*. From sandstone rocks only. **10** to **16.** For replies to these questions see former Reports.

Information collected by Mr. De Rance, from the Cromer Waterworks Company, Limited.

Analysis of Water.

County Analyst's Office and Laboratory, London Street, Norwich,
November 11, 1880.

	Grains per gallon
Total dissolved solids	21·2800
Free ammonia	·0056
Ammonia from organic matter	·0028
Nitrogen as nitrates or nitrites	none
Chlorine	2·2400
Equal to common salt	3·7100
Lime	7·2800
Magnesia	·6050
Sulphuric anhydride	1·4400
Equal to gypsum	2·4500
Oxygen required to oxidise organic matters	·0760
Natural hardness	15 degrees
Hardness after boiling	3·8 ,,

Remarks.—This water is undoubtedly to be ranked as a water of high-class purity, and in all respects is admirably adapted for dietetic purposes. The organic impurity is practically *nil*, and the mere trace which is found to be present is unquestionably mainly derived from vegetable sources of a perfectly harmless description. The hardness is also very moderate, and well within the limits which have been practically found conducive to health; at the same time it is quite sufficient to prevent any absorption of lead from metal pipes. By simple boiling the hardness is reduced to one-fourth of its original amount. I consider it an admirable water, both for domestic and general purposes.

(Signed) Francis Sutton.

Mr. G. H. Ogston, of 22 Mincing Lane, London, in his Report of January 11, 1881, after confirming the above analysis, goes on to say:—

'The sample sent me from the Cromer Reservoir has been analysed. It is clear and bright, and has a good appearance in addition to a brisk and agreeable taste.

'The analysis indicates that it is free entirely from pollution, and in my opinion it is an excellent water for drinking and for general use.'

Information collected by Braintree and Bocking Microscopical and Natural History Club.

1. Belonging to Messrs. S. Courtauld & Co., situate at Bocking Church Street, Essex. **1*a*.** July, 1865. No. **2.** 137·07 feet. **3.** 40 feet deep, 5 feet diameter; 244 feet deep, 8 inches diameter. **3*a*.** None. **4.** No pumping required. **4*a*.** When first sunk it stood about 8 feet *above* surface of ground. Not ascertained. **5.** Capa-

bilities not known. About 16,000 gallons is allowed to flow out of well. **6.** Under the peculiar circumstances of the case we cannot at present say. Have kept no record for this time. **7.** Cannot say at present. About 10 feet above stream. **8.** Analysis of one imperial gallon :—

Oxidisable organic matter	·22	Actual (saline) ammonia	·0350 grain.
Oxide of iron and alumina	·14		
Carbonate of lime	15·19	Organic (albuminoid) ammonia	·0028 ,,
,, of magnesia	8·25		
Sulphate of lime	7·67		
Chloride of magnesium	9·34		
,, of sodium	3·87		
Soluble silica	1·19		
Total solid constituents	45·87 grains		

No.		Feet
	Superficial Drift.	
9. 1.	Made ground	6
2.	Sandy clay	8
	Tertiary.	
3.	London clay	46
4.	Clay stone and cement stone, with small vein of sand yielding water	3
5.	London clay, with stones and shells	17
6.	Cement stone	1½
7.	London clay	3½
8.	Dark sandy clay, nearly all sand, slight traces of shells	6
9.	Sandy clay, a little lighter in colour than above	4
10.	Loose sand	2
	Lower London Tertiary.	
11.	Dark sand, slight trace of clay and shells	7
12.	Pebbles and London clay	1½
13.	Loose sand, light brown colour	15½
14.	London clay and stones	3
15.	Loose sand	7
16.	Mottled clay	2
17.	,, ,, and sand	4
18.	,, ,,	8
19.	,, sand, with slight mixture of clay	4
20.	Light-coloured sand	14
21.	Dark sand, very smooth, almost like mud	21
22.	Green sand	2½
	Secondary.	
23.	Chalk, in which an additional bore of 57½ feet was made	57½
	Total	244 ft.

9*a*. In Nos. 4 and 23. **10.** None near. **12.** Do not know of any. **13.** No. **14.** No. **15.** No. **16.** At first (July 1865) the well supplied about 9,000 gallons of water per hour above the surface of ground. July 1867. The well up to this time had been allowed to run to waste night and day, and it was found that the quantities supplied had diminished to 2,000 gallons per hour. Since then it has been economised, and it is found now that at any particular time it will supply about 5,000 gallons per hour.

Weekly Record of the Level of Water in Messrs. Samuel Courtauld and Co.'s well, Bocking, Braintree, Essex. Observations made at 6 A.M. *on Monday mornings. No water is drawn from well on Sunday.*

Date, 1883		Above surface of ground	Below surface of ground	Rainfall for previous week	Remarks
Jan.	1	16 inches	—	1·10	
„	8	12½ „	—	·40	
„	15	18 „	—	·67	
„	22	11½ „	—	·13	
„	29	16 „	—	·94	
Feb.	5	11½ „	—	·72	
„	12	13 „	—	1·84	A very general heavy fall throughout the county.
„	19	13 „	—	·73	
„	26	10½ „	—	·03	
Mar.	5	11½ „	—	·22	
„	12	16 „	—	·97	
„	19	15 „	—	·66	
„	26	19 „	—	Nil	Easter. No water used on the 23rd, 24th, or 25th.
April	2	13 „	—	·27	
„	9	12 „	—	Nil	
„	16	13½ „	—	Nil	
„	23	14½ „	—	·47	
„	30	16 „	—	1·12	
May	6	15 „	—	·02	
„	15	14 „	—	·90	Whit Tuesday. No water used on the 16th.
„	21	13 „	—	Nil	
„	28	13½ „	—	·59	
June	4	13 „	—	Nil	
„	11	12½ „	—	·04	
„	18	14 „	—	·81	
„	25	15 „	—	1·31	
July	2	13 „	—	·97	
„	9	15 „	—	·24	
„	16	13 „	—	·89	
„	23	14 „	—	·83	
„	30	15 „	—	·27	
Aug.	7	14 „	—	—	Tuesday. No water used on the 6th.
„	13	12 „	—	—	

NOTE.—The rainfall is taken from the record kept at Fennes, Braintree (observer, Mr. S. Tabor), which is about one mile from well.

Collected by Mr. Thos. S. Stooke, C.E.

1. The well is situated at the Wem Pumping Station, near the village of Preston Brockhurst, about $3\frac{1}{4}$ miles to the south-east of the town of Wem. The works for utilising the supply are in course of construction. **1***a*. A trial boring was put down in March 1882, and the well was sunk in the same year. **2.** Approximate height above mean sea-level is 270 feet. **3.** The well is $66\frac{1}{2}$ feet in depth, and 6 feet in diameter. The bore-hole is 90 feet in depth, and three inches in diameter. **4** and **4***a*. No pumping has taken place since the drift-way was finished on December 15, 1882.

Three days afterwards, *i.e.*:—

	Feet
On December 18, the water-level was . .	32½ from surface.
„ February 6, „ „ . .	31¼ „ „
„ May 23, „ „ . .	30¾ „ „
„ July 2, „ „ . .	30 „ „

At this latter level it remains. **5.** The quantity of water capable of being pumped at the time of completing the operations was 150,000 gallons in the twenty-four hours, being more than four times the quantity required for the present supply of the town of Wem. **6.** The water-level does not appear to be affected by local rains, and it stands (**7**) about 24 feet under the level of water in the neighbouring water-course. **8.** The analysis and remarks by Dr. Franklin, F.R.S., are as follows:—

'November 28, 1882.—Results expressed in parts per 100,000.

'Total solid matter	18·80
Organic carbon	·126
Organic nitrogen	·025
Ammonia	0
Nitrogen as nitrates and nitrites	·079
Total combined nitrogen	·104
Previous sewage or animal contamination	0
Chlorine	1·4
Temporary hardness	4·8
Permanent hardness	6·0
Total hardness	10·8

'*Remarks.*—Slightly turbid, palatable, no poisonous metals. This water, although slightly turbid, contains but a moderate amount of organic matter, and chiefly of vegetable origin. It is of good quality for drinking, and being fairly soft, it is also well suited for washing and all other domestic uses.'

9. The section is as follows:—

Soil and clay	8 feet
Fine red sand	2 feet
Lower soft variegated sandstone	80 feet

10 and **11.** There was a little surface water finding its way through the 2 feet of sand, but it is entirely kept out of the well, and also out of the bore-hole. **12.** The well is situated about 600 yards from the outcrop of the marl measures on the west. **13** and **14.** There are no salt springs known to exist in the neighbourhood. **15.** No wells have been discontinued in the neighbourhood in consequence of the water being brackish.

Collected by Mr. Thomas S. Stooke, C.E.

1. The 'Mine Well,' in the parish of 'The Clive,' Shropshire. **1*a*.** The well was sunk in 1868, and has not been deepened since. **2.** The well is about 373 feet above mean sea-level. **3.** The depth of well is 183 feet; diameter, 8 feet. There is a bore-hole, but depth has not been ascertained. **3*a*.** There is one drift-way at bottom of well, about 40 feet in length. **4.** The water-level is 142½ feet from the surface. **4*a*.** The level of water has not varied since the bore-hole was put down. **5.** The quantity of water capable of being pumped is considerable. The water is at present only drawn by means of a windlass, for the use of adjoining houses. **6.** The water-level has not varied. **7.** The water-level is not affected by local rains, and stands about 233 feet above mean sea-level. **8.** Analysis by Dr. Voelcker, dated September 16, 1869:—

Organic and volatile matter	1·96
Oxide of iron and alumina and fine suspended clay	1·05
Silicious matter	1·75
Carbonate of lime	4·26
Sulphate of lime	3·31
Carbonate of magnesia	1·44
Chloride of sodium	2·48
Total residue per gallon	16·25

Remarks.—'I have carefully examined this water, and, am very glad to say, found it free from any traces of copper. It is a good and soft water, and, in my opinion, a perfectly wholesome drinking water.' **9.** The well is sunk in the Bunter series of the new red sandstone, the dip of the strata being north-north-west. **10.** There are no surface springs. **12.** The marl measures outcrop about 500 yards to the north. **13.** No salt springs. **14.** No salt springs known in the neighbourhood. **15.** No wells have been discontinued on account of the water being brackish.

Collected by Mr. Thomas . Stooke, from Mr. G. J. Butter, Borough Surveyor, Shrewsbury.

1. Conduit Head, near Crow Meole. **1***a*. 1556. **2.** 236 feet. **3.** Depth, 6 feet; diameter, 4 feet. No bore-hole. **3***a*. No drift-ways. **4.** Stands about 1 inch lower at night than morning. **5.** Estimated daily consumption, 50,000 gallons. **6.** Lower in autumn than spring. No. **7.** I think it is to a slight extent, within a few days.

8.	Total solid impurity	38·48
	Organic carbon	·040
	„ nitrogen	·016
	Ammonia	·001
	Nitrogen, as nitrates and nitrites	·449
	Total combined nitrogen	·466
	Previous sewage or animal contamination	4·180
	Chlorine	2·30
	Temporary hardness	20·4
	Permanent „	10·9
	Total „	31·3

Remarks.—Clear. Results of analyses expressed in parts per 100,000. **9.** New red sandstone.

Collected by Mr. Thomas S. Stooke, from Mr. W. J. Wyley.

1. Wellington Workhouse, Salop. **1***a*. 1876. No. **3.** 81 feet; diameter, 5 feet. No bore. **3***a*. None. **4.** 69 feet. Water flows in as fast as pumped, say 1,500 gallons per hour. **4***a*. 77 feet for about two first years, as far as present experience goes. **5.** 2,000 gallons per hour may be pumped continuously. Water flows out of a crack in the rock. About 2,000 gallons per day. **6.** No. Increased the last four years. **7.** No. **8.** When boiled, forms strong lime incrustation in the boilers; when cold, oxidises the lead and eats away lead tanks. **9.** New red sandstone. **11.** Yes. **12.** Is on the fault between the new red and Caradoc sandstones. **13.** No. **14.** Yes; within three miles. **15.** No.

Appendix II.—List of Queries Circulated.

1. *Position* of well or shafts with which you are acquainted? **1***a*. State *date* at which the well or shaft was originally sunk. Has it been deepened since by sinking or boring? and when? **2.** Approximate *height* of the surface of the ground above Ordnance Datum (mean sea-level)? **3.** *Depth* from surface to bottom of shaft or well, with diameter? *Depth* from surface to bottom of bore-hole, with diameter? **3***a*. *Depth* from the surface to the horizontal drift-ways, if any? What is their length and number? **4.** *Height* below the surface, at which water stands *before* and *after* pumping. Number of hours elapsing before ordinary level is restored after pumping? **4***a*. *Height* below the surface at which the water stood when the well was first sunk, and height at which it stands now when not pumped? **5.** *Quantity* capable of being pumped in gallons per day of twenty-four hours? Average quantity daily pumped? **6.** Does the *water-level* vary at different seasons of the year, and to what extent? Has it diminished during the last ten years? **7.** Is the ordinary *water-level* ever affected by local rains, and, if so, in how short a time? And how does it stand in regard to the level of the water in the neighbouring streams, or sea? **8.** *Analysis* of the water, if any. Does the water possess any marked *peculiarity?* **9.** *Section* with nature of the rock passed through, including cover of Drift, if any, with *thickness?* **9***a*. In which of the above rocks were springs of water intercepted? **10.** Does the cover of Drift over the rock contain *surface springs?* **11.** If so, are these *land springs* kept entirely *out* of the well? **12.** Are any large *faults* known to exist close to the well? **13.** Were any *brine springs* passed through in making the well? **14.** Are there any *salt springs* in the neighbourhood? **15.** Have any wells or borings been discontinued in your neighbourhood in consequence of the water being more or less *brackish?* If so, please give section in reply to query No. 9. **16.** Kindly give any further information you can.

Report of the Committee, consisting of Professor W. C. WILLIAMSON, Mr. THOS. HICK, *and* Mr. W. CASH (*Secretary*), *appointed for the purpose of investigating the Fossil Plants of Halifax.*

WE regret to have to state that our efforts to investigate the Fossil Carboniferous Flora of Halifax have been less successful this year than in the previous one. The reason for this is sufficiently obvious. All the more abundant objects characteristic of the locality are now well understood. The gaps that need to be filled are connected either with the rarer forms, or with unusual conditions of the more common plants. Nevertheless we have not been wholly without success. We have obtained clear evidence of the existence of at least two new types of Rachiopteris—which are most probably stems or petioles of ferns. A third one is a curious stem, in which the vascular bundle approaches that of a Lepidodendron in its defined cylindrical form, surrounding a cellular pith, a condition rarely seen amongst ferns. But we have found no traces of leaves attached to it, as is always the case with the young twigs of Lepidodendra.

Another stem is an undoubted Lepidodendron of a very interesting type. Its central vasculo-medullary axis corresponds closely with that of Lepidodendron selaginoides, except that the barred or reticulated medullary cells of that species are absent from the new plant. Like L. selaginoides the new form has a secondary exogenous vascular zone of barred vessels, but of a primitive type that is intermediate between the perfect condition of that zone in L. selaginoides, and its extremely rudimentary form in L. Harcourtii. In the transverse section the zone appears more perfectly and regularly developed than in L. Harcourtii, which plant it also resembles in the extremely small size of its vessels; but its most characteristic feature is shown in the longitudinal section, in which we find these numerous secondary vessels meandering as they ascend through a mass of cellular tissue, so that in such sections cells and vessels appear to be intermingled without order or special arrangement.

We have obtained a series of roots or rootlets which have much of the general aspect of those of Stigmaria. But they possess the very distinctive feature of giving off secondary rootlets in perfect verticils, a very unusual feature in fossil root-organs. We have also obtained further illustrations of the presence of tylose-cells in the interior of the tissues of other plants. For some time we were only acquainted with these curious growths in the interiors of the vessels of ferns. But we have now obtained them in the vessels of a Lepidodendron stem, and also in the cortical cells of some ferns, as well as in those of the Lyginodendron Oldhamsium. We may further add that new fragments continue to be met with, showing the existence in these beds of strange forms of plant-life, of the nature and general morphology of which we are wholly ignorant. Such fragments are like a few scattered grains of gold at some new 'diggings.' They afford a strong stimulus to further research, since they are proofs that unrevealed treasures continue to be hidden in these Yorkshire and Lancashire carboniferous nodules.

Fourth Report of the Committee, consisting of Dr. H. C. Sorby *and* Mr. G. R. Vine, *appointed for the purpose of reporting on Fossil Polyzoa. Drawn up by* Mr. Vine (*Secretary*).

Part I.

Cretaceous Polyzoa. British area only.

The Polyzoa of the Cretaceous epoch, especially in foreign localities, have been closely studied by Palæontologists, and many valuable memoirs published by foreign authors. In his 'Petrifacta Germaniæ,' Goldfuss described and figured nearly fifty species. Hagenow, in his Palæontological works, accepts many of those previously described by Goldfuss and other authors, renames some, and adds to them nearly two hundred species besides. D'Orbigny also adds considerably to the number of Cretaceous species, discovered in the beds in the neighbourhood of Paris, and his admirable figures of some of these have increased very largely our knowledge of their varied forms. The rich Cretaceous beds of America have been partly investigated by Mr. Ulrich and by other American authors, but only a few species are, as yet, fully described, and many of the species are still undescribed.

Sir H. P. De la Beche, in his apology for the introduction of the elaborate lists of organic remains in his 'Geological Manual,' [1] says:—'Considerable attention has certainly been paid to such catalogues, as the zoological character of certain rocks is now the subject of much research, and as the result of such investigations may be the knowledge of some of the principal conditions under which the fossiliferous rocks were produced. Moreover, the author considered that, for practical purposes, there was no alternative between rendering them as perfect as his means of information would permit, and omitting them altogether. It must, however, be confessed that, though constructed from apparently the best authorities, these lists require severe examination, for, unfortunately, the study of organic remains is beset with two evils, which, though of an opposite character, do not neutralise each other so much as at first sight may be anticipated: the one consisting of a strong desire to find similar organic remains in supposed equivalent deposits, even at great distances; the other being an equally strong inclination to discover new species, often, as it would seem, for the sole purpose of appending the apparently magical word *nobis.*' Between one and the other of these two extremes the Palæontologist is almost sure to slide; and though the caution, with its quiet innuendo, may be old, it is none the less valuable in an inquiry like the present.

The list of Cretaceous Polyzoa, given by De la Beche contains no fewer than about fifty-six or fifty-eight species. Many of these bear the name of Goldfuss, but it is impossible to say whether the author intended the list as a British, or merely as a Cretaceous one. In all probability it was the latter. In his 'Catalogue of British Fossils,' Professor Morris admits about eighty species, distributed amongst thirty-five genera, many of these bearing the names of French authors. Professor John Phillips,

[1] Ed. 1832, Preface.

in his work on 'The Geology of Oxford and the Valley of the Thames,' furnishes a list—about forty-eight species—of British Cretaceous Polyzoa. In Dr. Mantell's works, and also in Dixon's 'Geology of Sussex,' many species are partially described and figured.

The best stratigraphical list of species known to me is the one furnished by Mr. Newton in the 'Catalogue of Fossils in the School of Mines—Cretaceous Division,' and as this is an account of actual specimens gathered from various horizons and from very wide localities in the British area, I shall make it the basis of this Report. As I have only partially examined the collection, I must depend upon the species in my own cabinet, and those lent to me by Miss E. C. Jelly, for furnishing the minute details necessary for this Report. It may be as well, however, to give the various horizons in which Polyzoa have been discovered and catalogued.

Lower Greensand, Speeton Clay, &c.,	20	species,	13	genera.
Blackdown Series—Traces only.				
Upper Greensand Series . .	17	„	16	„
Lower Chalk	2	„	2	„
Upper Chalk	13	„	12	„

Only some of these, according to Mr. Newton, range from the lower to the upper beds.

As in my previous Report on Jurassic Polyzoa, I shall adhere as closely as possible to the classification of the Rev. Thomas Hincks, as given in the 'British Marine Polyzoa,' beginning with the Cyclostomata.

Class POLYZOA.

Sub-order CYCLOSTOMATA, Busk.

Family I. CRISIIDÆ, Busk.

No fossils, belonging to this family, are at present known to have existed in either the Jurassic or Cretaceous epochs.

Family II. (1880). TUBULIPORIDÆ, Hincks.

1. STOMATOPORA, Bronn.
2. TUBULIPORA, Lamarck.
3. IDMONEA, Lamouroux.
4. ENTALOPHORA, Lamx.
5. DIASTOPORA, „ (pars).

Genus STOMATOPORA, Bronn, 1825.
= *Alecto*, Lamx.

'*Zoarium* repent, wholly adnate, or free at the extremities, or giving off erect processes; simple or branched; branches more or less ligulate. *Zoœcia* in great part immersed, arranged in a single series, or in several, which take a linear direction or are very slightly divergent.'—'Brit. Mar. Poly.' p. 424.[1]

The typical *Stomatopora* of the Cretaceous Rocks are of a very simple character. Only three species are given by Morris, three by Phillips, and one by Mr. Newton in his 'School of Mines Catalogue.'

[1] The nearer we approach the Cainozoic and recent types of Polyzoa, the greater is the necessity for extreme caution in our grouping of the fossil forms. I have, therefore, in this Report adopted the generic characters of Hincks in his own words, and have endeavoured to limit the various groups accordingly.

Alecto (= Stomatopora) *gracilis*, Milne-Ed., Morris.
" " *ramea*, Blainv. "
" " *ramosa*, Michelin "

Phillips adds *Alecto Calypso*, D'Orb., and Mr. Newton *Alecto reticulata*, D'Orb.

STOMATOPORA GRACILIS, Milne-Ed.[1]

Alecto gracilis, M.-Ed. (pars). Woodward's 'Geology of Norfolk' (pars). Dixon's 'Foss. Sussex' (pars).

Zoarium wholly adnate; branches linear, delicate, rarely, if ever, anastomosing. *Zoœcia* in a single series, thick, or bulging at the nodes;[2] orifice circular, with a thin peristome. *Oœcia*, an inflated cell, with orifice depressed.

Localities.—Up. Chalk, Wilts (Phillips). Beachy Head (Miss Jelly). Sussex (Dixon).

I limit, as above, the typical *S. gracilis* of Milne-Ed., for the very special reason that I find in the catalogues of collectors and others that the species is very loosely identified. In the specimen before me three cells occupy a line and a half, but the cells vary in length, and the average may be taken as three cells to a line and a quarter, or a line and a half. Generally the branching takes place at the distance of three cells apart, an inflated cell (*oœcia*) occupying the apex of a branch just below the node. Though distinct from, this species is more closely related to *S. dichotomoides*, D'Orb., than to any other of the Oolitic species; the latter, however, are more bulky in the size of the cells.

STOMATOPORA RAMOSA, Mich.

? *Alecto ramea*, D'Orb. Phill. 'Geo. of Oxford (Greensand Species).' *Diastopora ramosa*, Michelin. Dixon, 'Geo. Sus.'

Zoarium adnate, irregularly branching, occasionally anastomosing. *Zoœcia* ranging from a single series to multi-serial in the same branch, dilated towards the nodes; orifice circular, peristome slightly elevated, and occasionally rugose on the surface. *Oœcia* large, sometimes involving two cells, also rugose in front.

Localities.—Upper Greensand, Warminster. Upper Chalk, Sussex (Dixon). Beachy Head (Miss Jelly).

This species, like the first, is also confounded, but in the specimens before me, marked *Diastopora ramosa*, Mich. (Dixon, 'Sussex'), there is to some extent the same type of cell found in many of the *Diastoporidæ*. Still, as Mr. Hincks only includes in the adnate *Diastopora* 'discoid or flabellate' forms, I have removed the species to the genus *Stomatopora* on account of its closer resemblance to species of that genus. In all probability the *Alecto reticulata*, D'Orb. (Brit. specimens), should likewise be removed to this species as a synonym.

Genus TUBULIPORA, Lamarck.

This genus is at present unknown to me as a Cretaceous fossil. Hagenow gives one species only, *T. parasitica*, Hagenow.

[1] In every case where my material admits of redescription, I make no apology for doing so, because I believe that this will be appreciated by workers.

[2] I have used the word *node* to indicate the part just below the branching of the cells, or of the stem. At this part in the *Zoarium* there is frequently a knot or a bulging, and it is also frequently here that the *Oœcia* may be detected in species.

Genus IDMONEA, Lamx.

'*Zoarium* erect and ramose, or (rarely) adnate; branches usually triangular. *Zoœcia* tubular, disposed on the front of the branches, ranging in parallel, transverse, or oblique rows on each side of a mesial line.' —Hincks, 'Brit. Mar. Polyzoa,' p. 450.

This 'world-wide' genus is, so far as I am acquainted at present, very poorly represented in our British Cretaceous strata. Mr. Hincks ('Brit. Mar. Polyzoa,' p. 451) says 'many charming forms occur in the Cretaceous deposits,' but these I have not seen. In the Chalk Marl of Charing we have a species very closely resembling *Idmonea* (Retepora) *disticha*, Goldf. It is only found in minute fragments, but it may be easily distinguished from the species of the next genus, by having the zoœcia disposed on the front of the branches only. There are also traces of the delicate *Idmonea Comptoniana*, Mantell, but it is very rarely that specimens can be found even half the size of the specimen figured by Mantell. The author says: 'This delicate Polyzoon (*coral*, Mant.) is dichotomous, cylindrical with elongated distinct cells, disposed in triplets at regular distinct intervals on one side of the stem.'[1] Mantell also figures and describes a species which he calls *Idmonea Dixonia*, but I cannot identify the type. It 'is found in the chalk of Kent and Sussex, often forming a cluster of branches two or three inches in circumference. The surface of the stems is covered with minute pores, and the cells are distinct and placed in single rows on the margin.' It is very well illustrated in the 'Medals of Creation,' Lign., figs. 6 and 12, p. 284.

Many of the *Idmoneæ* (?) of the Cretaceous epoch described by D'Orbigny, Mr. Busk places doubtfully with *Stomatopora* as synonyms.[2] A mere casual reference to the synonyms of *Idmonea atlantica*, Forbes, will show how dangerous it would be to give specific names to the fragments described above. I have, however, given a list of British species described by Dixon and others.

Idmonea Comptoni, Mantell.	Up. Chalk, Chichester.
,, *cretacea*, Milne-Ed. = *I. Dixoni*, Mantell (Morris).	,, Sussex, Kent, Hampshire.
,, *gradata*, Defr. = *Retepora disticha*, Goldf.	

In Mr. Wiltshire's paper on 'The Red Chalk of England' (Geologist, 1859, p. 275), a list of Cretaceous fossils is given, and one species of Polyzoa is identified as *Idmonea dilatata*, D'Orb.[3] In the 'Catalogue of the School of Mines' (Cretaceous), two species are given from the Up. Chalk:

Idmonea cretacea, Milne-Ed., Up. Chalk.
,, *gradata* ? Defr.

Hagenow describes no fewer than fifteen species of IDMONEA—breaking up Goldfuss's *Retepora clathrata* and *R. disticha*, out of which he makes seven species; the rest are his own. One species—*Retepora truncata*, Goldf.—is taken with *T. felix*, Hag., as types of a new genus, *Truncatula*, Hagenow.

[1] *Medals of Creation*, p. 288; Lign. 64, fig. 14.
[2] *Crag Polyzoa*, p. 113.
[3] See also *Brit. Mus. Catalogue*, Pt. iii. (Busk), 1875, p. 15.

Genus ENTALOPHORA, Lamouroux.

Restricted by the Rev. T. Hincks, 'Brit. Mar. Polyzoa.'
=*Pustulopora*, Blainv., Busk, 'Crag Polyzoa,' 'Brit. Mus. Catalogue,' pt. 3.

'*Zoarium* erect and ramose, rising from a more or less expanded base, composed of decumbent tubes; branches cylindrical. *Zoœcia* tubular, opening on all sides of the branches.'—'Brit. Marine Polyzoa,' p. 455.

The genus *Entalophora*, as defined and limited by Mr. Hincks, will embrace a variety of species. The *Spiropora* of both Jules Haime (Oolitic Polyzoa, 'B. A. Rep.' iii.) and Professor Reuss may be conveniently included. There are, however, so many special features about the *Spiroporæ* described by these authors, that I have for a long time hesitated whether to continue with, or give up the further use of, the generic name. The clause in the above—'composed of decumbent tubes'—may be applied with perfect safety to most of the Mesozoic species, and the adoption of the broader term will get rid of a number of genera and species that have been founded upon *habit* only, rather than upon the character and disposition of the cells in the *zoarium*.

The following analysis of genera and species will enable the palæontologist to appreciate more fully the varied character of the fossils which the genus *Entalophora* will cover.

The first species of *Spiropora*, Lamx., described by Haime in his 'Jurassic Bryozoa' (1854), is *S. elegans*, Lamx., from the Great Oolite of Ranville. This species is 'cespitose' with cylindrical branches which often coalesce. The same species is the *Cricopora elegans* of Blainville, Bronn, Milne-Edw., and Michelin; D'Orb. describes it as *Spiropora*. Another of the species of Lamouroux is *S. cæspitosa*, which, so far as the character of the cells may be taken as evidence, may with equal propriety be called *S. elegans*. Some specimens are rather more tufted, and the lateral cells are slightly produced. The species is synonymous with *S. capillaris*, Lamx. This is also called by Blainville *Cricopora*, and *Entalophora* by D'Orb. The *Millepora straminea* of Phillips ('Geol. of York') is, by Haime, called *Spiropora*, by D'Orb. *Intricaria* (1850), *Laterotubigera* (1853), and *Entalophora* (1854). Our British specimens of this species may, to some extent, justify the generic appellation *Intricaria*, Defranc, on account of the continuous inosculation of the branches. I may almost affirm that the habit is an unvarying one as regards this species; and a similar species found in the Haldon Hill Greensand inosculates in the same manner. But as I am following the Rev. Thomas Hincks in his classification, it is impossible to accept 'habit' as a generic characteristic in this Report. The synonyms of the species are also very significant, and compel us to limit the types. I cannot, however, agree with Professor D. Brauns ('Bryozoa of the Middle Jura') that *Ceriopora verticillata* is synonymous with Phillips's species. Other species, also described by Haime as *Spiropora*, are *Entalophora*, D'Orb.; or *Cricopora*, Blainville. Amongst Cretaceous fossils a similar mixture of generic terms (founded upon habit chiefly) takes place, so that we may regard the terms *Spiropora*, Lamx.; *Intricaria*, Defranc; *Cricopora*, Blainv.; *Melicertites* (pars) Roemer; *Tubigera*, D'Orb.; *Stichopora*, D'Orb.; *Laterotubigera*, D'Orb.; *Pustulopora*, Blainv.; *Peripora*, D'Orb., as synonyms only of *Entalophora*. It must not be assumed, however, that, in getting rid of a number of generic

terms thus, we get rid of difficulties. Not a single genus has been founded by these various authors, which may not, under a different system of estimating their value, have something said in favour of its continuous adoption.

I have been supplied by Mr. J. M. Nickles, of Cinncinati, with a few of the Cretaceous Polyzoa from Arkansas in America, and, as these closely resemble species found in our own strata—I may say identical with our own—I shall be able to give fuller details of our British Cretaceous fragments.

ENTALOPHORA GRACILIS, Goldfuss.

Ceriopora gracilis, 'Petrif. Germ.' p. 35, tab. 10, fig. 11.
Cricopora ,, Morris, 'Catalogue Brit. Foss.'
Ceriopora mammillosa (pars).
,, *ramulosa* (pars).

The variable character of this polyzoon renders identification very difficult indeed. The description and figures of Goldfuss are very good, especially the figures, but apparently, in the diagnosis, but little regard has been paid to growth. In the Lower Greensand of Farringdon the species is very characteristic, and in all probability two or three others may be reduced to mere synonyms of this well-marked type. The branches of some of the specimens that I have in my cabinet are a half of a line in diameter, whilst others are about $\frac{1}{10}$ of an inch in breadth; yet the superficial characters of both are the same, only in the smaller specimens there is a less number of cells to the transverse section. The following may be accepted as the diagnosis of this species.

Zoarium ramose, cylindrical, rounded at the apices, or growing extremity; varying in diameter from $\frac{1}{24}$ to $\frac{1}{10}$ of an inch. *Zoœcia* contiguous, showing the orifices of the cells only, tubes rarely, if ever, exposed; occasionally perfect, and, when this is the case, the surface of the branch is smooth, or the peristome of the cell slightly extended; when worn, the cell-openings are oval, arranged in series across the branch, or, more correctly speaking, arranged diagonally.

Localities.—Lower Greensand, Farringdon. Upper Greensand, Warminster.

ENTALOPHORA PUSTULOSA, Goldfuss.

Ceriopora pustulosa, Goldf. 'Petrif. Germ.' p. 37, tab. 11, fig. 3.
Pustulopora ,, Morris, 'Cat. Brit. Foss.'
Ceriopora mammillosa, ? Roem. (pars) of authors.

Zoarium variable, sometimes clavate, at other times branching, thick or bulgy towards the nodes. *Zoœcia* arranged in series—spirally—around the branch, about six to the line in a diagonal, five to the line, in a longitudinal direction; cells pustulose at the orifice, peristome raised; crowded at the apices. When worn, the cell-openings are elongately oval, much larger than in the more delicate *E. gracilis*.

Localities.—Lower Greensand, Farringdon.

The above is the description of the species generally met with in the Greensand of Farringdon. In the Greensand of Haldon Hill, Devon, there is a species having a similar external pustulose character, but the interspaces are porous; so also is an apparently similar species found in the Upper Chalk.

ENTALOPHORA INCERTA, n. sp.

Zoarium very delicate, erect and ramose, branches varying in their character, from subcylindrical to cylindrical, but bulging at the nodes. *Zoœcia* tubular elongated, or depressed, partially decumbent, occasionally produced towards the distal extremity, opening on all sides; cells punctured. *Oœcia* an inflation of the *zoarium* or an inflated cell.

Locality.—Chalk detritus, Charing.

This delicate species seems not to have been referred to by authors. From the Cretaceous rocks of Pulaski Co., Arkansas,[1] I have a very similar species to the above, and I have not the least doubt but that the British and American forms may be considered identical.

Under the genus *Pustulopora*, Blainv., Hagenow describes from the Maestricht beds ten species, and under *Cricopora*, Blainv. = *Spiropora*, Lamx., two species, some of which bear his own name, others are either *Ceriopora* or *Pustulopora* species, of Goldfuss or Blainville. In the Cretaceous Catalogue of Species in the School of Mines, only one is referred to *Entalophora* (*E. ramosissima*, D'Orb.), and one to *Spiropora* (*S. cenomana*, D'Orb.). Besides the above, Professor Morris, and also Professor Phillips, add three others, none of which I can identify in my own collection.

Genus DIASTOPORA (Adnate), (part), Lamouroux.

'*Zoarium* adnate and crustaceous (or foliaceous), usually discoid, or flabellate, less commonly irregular in form. *Zoœcia* tubular, with an elliptical or subcircular orifice, crowded, longitudinally arranged, in great part immersed.'—'Brit. Mar. Polyzoa,' vol. i. p. 457.

Our British Cretaceous *Diastopora* are, so far as I am aware, very limited in the number of species. In his 'Catalogue of Brit. Foss.' Professor Morris gives the names of several, but I am only able to identify two species in the Lower Greensand—*D. congesta*, D'Orb., and *D. papyracea*, D'Orb. *D. Sowerbii*, Lonsdale, is not apparently a *Diastopora*, and *D. ramosa*, Mich., in Dixon's 'Geo. of Sussex' is a *Stomatopora*. I do not know the *D. Wetherelli* of Morris. I have therefore described below a very fine species from the Upper Chalk of Beachy Head (Miss Jelly's collection) which I have provisionally named

DIASTOPORA CRETACEA (n. sp. ?).

Zoarium adherent with a nearly circular outline, depressed in the central part, very much thickened at the edges by stunted (partially grown) cells, but without basal lamina. *Zoœcia* irregularly arranged, contracted towards the proximal and thickened at the distal extremities, separated by interspaces; orifice circular with a thickened peristome. *Oœcia* an inflated cell.

Locality.—Upper Chalk, Sussex (Miss Jelly's Cabinet).

The above is a true *Diastopora*, and specifically is very closely related to *D. oolitica*, Vine ('Quart. Jour. Geo. Soc.' August 1881), only that in the Cretaceous species the cells are less crowded than in the Oolitic. The cells and cell-orifices are similar, but the question with me is whether it would be wiser to extend the description of *D. oolitica* so as to embrace the more recent type, or whether we should keep the types of the two

[1] Sent to me by my friend J. M. Nickles, of Cincinnati.

epochs distinct. At the present time, and under present circumstances, I think the latter would be the wiser course to adopt, and then, when our British Polyzoa are better known, a closer alliance of types can be made. Hagenow describes only one species of *Diastopora*, *D. disciformis*, Hag.

? DIASTOPORA SOWERBII, Lonsdale. Dixon's 'Sussex.'

I am rather doubtful about this species. I have the generally recognised form in my cabinet, and for the present I allow the name to appear in this Report.

Biserial DIASTOPORA, Milne-Ed.

=*Mesenteripora*, Blainv.; *Bidiastopora*, D'Orb.: 3rd 'Brit. Assoc. Report.' Mihi. 1882.

DIASTOPORA RETICULATA (new sp. ?)

Zoarium reticulate formed by narrow leaf-like bands, having a width of about $\frac{3}{20}$ of an inch, and a breadth varying in thickness from about $\frac{1}{40}$ to $\frac{1}{30}$ of an inch; the leaf-like bands anastomose at irregular distances. *Zoœcia* tubular, delicate, and arranged in pretty regular, transverse lines across the width of the band, both on the exterior and interior surfaces of the *zoarium*; about twenty cells occupy one of these transverse lines; the orifices of the rows of cells are turned slightly upwards, and the proximal parts are depressed, so as to form a kind of ridge-and-valley surface. *Oœcia* ?

Locality.—Beachy Head, Hastings (Miss Jelly); and also in my own cabinet.

I am unable, from the various works at my disposal, to identify this peculiar Cretaceous Polyzoon. The habit of the species is unlike any other biserial *Diastopora* known to me, both in the disposition of the *zoœcia* and in the ribbon-like appearance of the *zoarium*. My own specimen is rather large, measuring one inch in length, and about a half-inch in breadth, but the section of the bands, when examined in a line, with the narrow back-to-back arrangement of the cells, shows the same biserial character as in some of the leaf-like but free (not reticulate) bands of the Oolitic epoch. There is a very striking likeness in this species to *Idmonea fenestrata*, Busk ('Crag Polyzoa,' p. 105, Pl. xv. fig. 6), but the branches of that species are said to be sub-trigonal, and often angular behind. In Miss Jelly's collection it is named *D. ramosa* ? Michelin. I cannot identify it as such.

Family III. HORNERIDÆ, Smitt.

= *Crisinidæ* (part), D'Orb.; *Idmoneidæ*, Busk, Crag. Polyzoa; 'Brit. Mus. Catalogue.' (See Hincks.)

'Zoœcia opening on one side only of a ramose zoarium, never adnate and repent.'—'Brit. Mar. Polyzoa,' vol. i. p. 467.

Family IV. HORNERIDÆ, Hincks.

Genus HORNERA, Lamouroux.

Zoarium erect, ramose, sometimes reticulate. *Zoœcia* tubular, opening on one side only of the branches, disposed in longitudinal series, the celluliferous surface often traversed by wavy anastomosing ridges. *Oœcium* a distinct chamber (not a mere irregular inflation of the surface of the *zoarium*), placed dorsally or in front. ('Brit. Mar. Polyzoa,' p. 467.)

The type *H. frondiculata*, Lamx., is a well-marked species, and is admirably described and figured by Mr. Busk in Pt. iii. (Cyclostomata), 'Brit. Mus. Cat.' p. 17, Pl. xx. figs. 1, 2, 3, 4. The genus is doubtfully represented in the Cretaceous epoch; but as the *Siphodictyum* of Lonsdale very closely resembles some of the admitted *Hornera* of Miocene age in continental catalogues, it may be well to admit it in ours also. Hagenow admits one species, *H. tubulifera*, Hag.

HORNERA? GRACILE, Lonsdale.

=*Siphodictyum gracile* (Lower Greensand, 'School of Mines Catalogue').

Family V. LICHENOPORIDÆ, Smitt.

Genus LICHENOPORA, Defrance.

'*Zoarium* discoid, raised, simple, or composed of many confluent disks, entirely adnate, or partially free, and sometimes stipitate, developed on a thin lamina which usually forms a border round it. *Zoœcia* distinct or connate, in single radiating lines, or multiserial.'—'Brit. Mar. Polyzoa,' pp. 471–2.

This genus will include the following genera of D'Orbigny, but species are not abundant in our British Cretaceous rocks.

α. Confluent disks: *Radiopora*, *Unicavea* (sp.), *Discocavea* (sp.).

β. Adnate with multiserial rays: *Actinopora*, *Discotubigera*. Mr. Hincks says: 'The genus is widely distributed both in space and time; in the Cretaceous beds it is represented by a large number of beautiful forms.'

'D'Orbigny has constructed a large number of genera, which are merely arbitrary groups based on very trivial modifications of this well-marked type.'

Genus RADIOPORA, D'Orb.

'*Zoarium* adnate, crustaceous, spreading irregularly, and composed of confluent disks like those of *Discoporella*; surface reticulate or cancellous; cells disposed in serial lines, radiating from the centres of the constituent disks.'—Busk, 'Cyclostomata,' p. 34.

In the Lower Greensand and also in the Chalk we have species that are and may be referred to this genus. In Prof. Morris's, Cat. Brit. Foss.' two species are named—*R. pustulosa*, D'Orb., and *R. millepora*, D'Orb.—both of which are before me, but there is a great difference in the two types. A species from the Chalk (Freshwater Bay, Isle of Wight) very closely resembles one of the figures of *Ceriopora diadema*, Goldfuss.

In retaining the genus *Radiopora* Mr. Busk remarks: 'In the majority of the fossil species referred by M. D'Orbigny to this genus, the zoaria are more or less rounded or bulbous, owing to the superposition of layer upon layer of the confluent disks; but in one, *R. Francquana* (l. c. p. 997, pl. 782, figs. 3–8 'Pal. Franc.') this superposition would seem to have taken place only to a very slight extent. In the two living forms I have referred to the same genus there is no superposition at all; but as the mode of growth is in other respects so exactly in accord with M. d'Orbigny's excellent description, I have not thought it expedient to institute another genus, or even subgenus, merely on that account.'

Mr. Hincks ('Brit. Mar. Polyzoa,' p. 473) does not make a separate

genus of *Radiopora*, but includes species in the genus *Lichenopora*: (I.) 'Colony simple, or composed of many confluent disks.' Certainly *L. hispida*, Flem., var. *meandrina*, Peach, bears a close resemblance to one of the Lower Greensand species, but in the absence of the peculiar markings about the orifice of the zoœcia in the fossil species I prefer to accept the authority of Busk rather than displace the species from the genus *Radiopora*, for the present at least.

RADIOPORA PUSTULOSA, D'Orb. 'Pal. Franc.'
? = *R. bulbosa*, D'Orb. ,, ,,

The Lower Greensand specimen is very large, frequently containing from twenty to thirty layers, and each layer composed of a number of disks, and the peculiar radial character of each disk may be examined if a group of them are slightly rubbed. It appears to me, however, that one specific name will indicate the superficial character of the Greensand specimens.

Locality.—Lower Greensand, Farringdon.

RADIOPORA MILLEPORA, D'Orb. 'Pal. Franc.' p. 992.
? *R. heteropora*, D'Orb.

This species is very different from the above, both in the character of the *zoaria* and in their general arrangement; but in the absence of sections showing the structure of the cells the superficial characters are comparatively useless in recent classifications.

Locality.—Lower Greensand, Farringdon.

RADIOPORA DIADEMA, Goldfuss.

Ceriopora id. Goldfuss, 'Petrif. Germ.' p. 39, tab. 11, fig. 12, 2.
Defrancia id. ,, Hagenow.

I have specimens of this beautiful species from the Chalk (Freshwater Bay). The *zoarium* is delicate and star-like, but I am unable to say anything about the structure of the cells. I merely refer to its existence as a British fossil in the hope that Palæontologists living in the Isle of Wight may have their attention directed to this as well as other species of Polyzoa.

Genus DOMOPORA, D'Orb.

'*Zoarium* massive, cylindrical or mammiform, simple or lobed, formed of a number of sub-colonies superimposed one upon the other, the whole surface porous. *Zoœcia* disposed in radiating lines, consisting of one or more series, on the free extremity of the stem or lobes.' Hincks, 'Brit. Mar. Polyzoa,' p. 481.

In this genus Mr. Hincks includes *Defrancia* (pars), *Ceriopora* (pars), Goldf., and *Stellipora* (pars), Hagenow, and the first species described, in 'Brit. Mar. Polyzoa,' is the beautiful Cretaceous fossil, *D. stellata* = *Ceriopora* id., Goldfuss. The one described is a recent species, nevertheless Mr. Hincks refers it to Goldfuss's type. I have never met with it as a British Cretaceous species.

The geographical distribution and range in time are given by Mr. Hincks thus: 'Norway, from Bergen to Bejan, 40–60 fath. (Sars). *In stratis arenoso-margaceis Westphaliæ*, Goldf.; Austro-Hungarian Miocene, Manzoni; Vienna Basin, Reuss.'

Family VI. HETEROPORIDÆ.

In this family, further on, I shall include the whole of the Fossil Polyzoa which have two sorts of openings on the surface, 'cells' and 'ostioles.' They are not a large group, but the species have distinct characters.

I have already pointed out the varied sources of information respecting *Heteropora* ('Brit. Assoc. Rep.' mihi, 1882, Fossil Polyzoa), both recent and fossil. Since this was written Mr. Ulrich in his 'American Palæozoic Bryozoa' has published descriptions of *Heteropora* from the Chalk of Arkansas, and I have been furnished by Mr. J. M. Nickles with specimens of Mr. Ulrich's species, and I cannot help remarking that there is a wonderfully close correspondence between the American and the British Cretaceous forms, so much so that it is difficult to distinguish between them.

Genus HETEROPORA, Blainville.

'*Zoarium* erect, cylindrical, undivided or branched, surface even, furnished with openings of two kinds; the larger representing the *orifices* of the cells, and the smaller the *ostioles* of the interstitial canals or tubes.'—Busk, 'Crag Polyzoa,' p. 120. (For synonyms see Busk.)

HETEROPORA DICHOTOMA, Goldfuss.

= *Ceriopora dichotoma*, Goldfuss, 'Petrifac. Germ.' p. 34, tab. 10, fig. 9 f.
= *Heteropora dichotoma*, Blainv. 'Man.' p. 417.
,, ,, Morris, 'Cat. Brit. Foss.'

As Mr. Busk remarks ('Crag Polyzoa,' p. 126): 'There are no means of judging correctly with respect to the *Heteropora* really intended by Goldfuss, except what are afforded by his very defective figures.' The several species described by Mr. Busk in the 'Crag Polyzoa' have the merit of being exact on minor details, and they are well illustrated, but there is one remark that I cannot resist directing attention to before describing the British Cretaceous *Heteropora*. In speaking of *H. reticulata*, Busk (unfortunately no figure is given of this species), the author says (p. 125): 'The peculiar characteristic of *H. reticulata* is the coarsely sulcate or reticulate aspect of the surface, which bears, in some respects, a strong resemblance to that of a *Hornera*, whence, as well as from the smallness of the interstitial pores and canals, this species may be regarded as intermediate between *Hornera* and *Heteropora*.' And Mr. Busk regards the species described as *H. lævigata* ? D'Orb. ('Crag Polyzoa,' pp. 125–6) as a probable link between these two genera and *Cricopora*, 'and perhaps as affording an additional proof of the artificiality of the not very satisfactory classification we are at present compelled to adopt of these Polyzoa.'

As I have carefully worked over the *Heteropora* of the Cretaceous epoch, I will give brief results of my investigations, reserving for future work more elaborate details.

HETEROPORA RETICULATA, Busk, 'Crag Polyzoa,' p. 121.

Ceriopora dichotoma (pars), Goldf. 'Petrif. Germ.' pl. x. fig. 9 c.
Heteropora ,, Hagenow (Busk as above).

The minute details furnished by Busk in his diagnosis compel me to place this species here, temporarily at least. Is this, however, synonymous with Haime's species ?

Locality.—Lower Greensand, Farringdon.

HETEROPORA sp.

As referred to previously there is present in the Greensand of Haldon Hill, Devon, a species very similar, in external characters, to *Entalophora pustulosa*, only that the orifices of the cells are smaller, the intermediate spaces are pitted, and the interstitial openings few in number. Eight cells occupy the space of a line in a longitudinal direction.

Locality.—Haldon Hill, Devon (collected by Miss Jelly).

HETEROPORA TENERA, Hagenow.

= *Ceriopora cryptopora* (pars), Goldfuss.

In the Lower Greensand, Farringdon, and also the Upper Greensand, Warminster, is a delicate species of *Heteropora* which Morris catalogues as *H. tenera*, Hagenow. There is but little difference in the structure of this species and the larger *H. crassa*, Hagenow, which is selected by the author from Goldfuss's as his type. Goldfuss includes the large and the small in his *C. cryptopora*, but Hagenow divides the honours and founds two types upon the one form. It is best, however, to refer to the labours of Hagenow, because if 'form &c.' were a character on which species could be accepted, the labours of this distinguished Palæontologist would prove of great advantage to the systematist. Hagenow's species are *H. crassa*, Hag., *H. dichotoma*, Goldf., *H. undulata*, Hag., *H. tenera*, Hag., *H. Dumonti*, Hag.

In giving descriptions of American Cretaceous *Heteropora* Mr. Ulrich remarks ('Amer. Palæoz. Bryozoa' (Cin. Soc. Nat. Hist. p. 143, 1882) that 'the species from Arkansas is nearly allied to *Zonopora variabilis*, D'Orb., from the Cretaceous of France.' The other species which the author describes and figures are *H. consimilis*, Ulrich, and *H. attenuata*, Ulrich.

Sub-order CHEILOSTOMATA, Busk.

Our British Cretaceous *Cheilostomata* are very limited in the number of species, but I believe that if a diligent search could be made our lists would be added to considerably. Prof. Morris in his 'Catalogue' gives only thirteen species, and I am unaware of the existence of any further additions to this list by British authors. In his Division D, URCEOLATA, Hagenow catalogues five species of *Vincularia*, fifty-four species of *Eschara*, three species of *Siphonella*, Hag., thirty-three species of *Cellepora* (Goldf. and Hag.), one species of *Stichopora*, Hag., two species of *Lunulites*, and five doubtful forms. A richness which we should be unable to boast of under the most careful researches—I fear so at least.

Genus MEMBRANIPORA, Blainville.

= *Flustra* (part); *Cellepora* (part), Hagenow; *Marginaria* (part), Roemer and Hagenow; *Dematopora* (part), Hagenow.

'*Zoarium* encrusting. *Zoœcia* quincuncial or irregularly disposed, occasionally in linear series, margins raised, front depressed, wholly or in part membranaceous.'—'Brit. Mar. Polyzoa,' p. 128.

It is impossible under present circumstances, and with the poor material at my disposal, to work out the Cretaceous *Membranipora*. I will therefore give short notes of the species that have come under my own observation, in the hope that better materials will be forthcoming.

MEMBRANIPORA ROEMERI.

? *Marginaria Roemeri*, Lonsdale, Dixon's 'Sussex.'

This species is generally met with in small patches, and the cells are occasionally elongate and compressed towards the proximal extremity, at other times compressed so as to appear like the cells of *M. angulosa*. Reuss.

Orifice of the cell semicircular, area depressed.

Locality.—Upper Chalk, Sussex.

In Miss Jelly's collection there is a small specimen marked *Marginaria*, but it does not appear to me to be a young colony of *M. Roemeri*. There is in the specimens the same semicircular mouth, but the front of the cell is raised not depressed, and smaller cells of the same character intervene between the larger.

MEMBRANIPORA INELEGANS.

Flustra ? inelegans, Lonsdale, Dixon's 'Sussex.'

This species is found in large and small patches. In the general arrangement and character of the cells this seems to remind one of the recent *M. Lacroixii*, Audouin. The Cretaceous fossil is much more compressed in the colonial growth than I have ever seen in the recent species, but none of the areas of the cells are like *M. Savartii*, Aud., which Mr. Busk ('Crag Polyzoa,' p. 31) identifies with *M. Lacroixii*.

Locality.—Upper Chalk, Sussex.

MEMBRANIPORA sp.

? Allied to *M. Hookeri*, J. Haime.

Prof. Reuss, in his 'Alpine Tertiary Polyzoa,' figures a specimen of *M. Hookeri* which resembles so closely the Cretaceous specimen before me, that I can hardly assign to it any other name. There is a larger colonial growth in the Cretaceous specimen than in any of the Tertiary specimens in my possession, and the walls are thicker; in other respects the resemblance between the Cretaceous and the Eocene species is remarkably close. With some little doubt, however, I place it as an allied form, rather than give to it a new name.

Locality.—Upper Chalk, Sussex (Miss Jelly).

Genus CRIBRILINA, Gray.

'*Zoarium* encrusting. *Zoœcia* contiguous, having the front more or less occupied with transverse or radiating punctured furrows; orifice semicircular or suborbicular.'—'Brit. Mar. Polyzoa,' p. 184.

CRIBRILINA RADIATA, Moll.

For references, &c., see Hincks (loc. cit. pp. 185, 190).

I have no record of this species occurring in our British Cretaceous rocks. The forms are incrusting on fragments of Echinodermata from

Genera and Species	Synonyms	Lower G.S.	Upper G.S.	Lower Chalk	Upper Chalk	Pages in Cat.
		1	2	3	4	5
TUBULIPORIDÆ.						
STOMATOPORA, Broun.	= *Alecto*, Lamx., Busk. . .					6
reticulata, D'Orb. .		*				
PROBOSCINA, Subgen. .						
cornucopiæ, D'Orb. .		*				7
ramosa, D'Orb. .		*				
IDMONEA.						
cretacea, M.-Ed. .					*	
gradata? Def. .					*	
triangularis, D'Orb.	= *Crisina triangularis* .				*	
DIASTOPORA (adherent)						
congesta, D'Orb. .		*				
papyracea, D'Orb. .		*				
? *Sowerbii*, Lonsd. .			*			
? *tubulus*, D'Orb. .			*			
ENTALOPHORA, Lamx.	= *Spiropora* . .					
ramosissima, D'Orb.	= *Diastopora* .	*	*			
Francquna, D'Orb. .	= *clausa Fran.* .		*			
? micropora, D'Orb. .	= „ *Micro.* .		*			
cenomana, D'Orb. .	= *Laterotubigera, Spiropora, Cricopora* . .		*			
pustulosa, Goldf. .	= *Pustulopora* .				*	
LICHENOPORIDÆ.						
Radiopora.						
elegans, Mich. . .	= *Actinopora* . .	*				
bulbosa, D'Orb. .		*				
heteropora, D'Orb. .		*	*			
pustulosa, D'Orb. .					*	
Neocomiensis, D'Orb.	= *Discocavea* .	*				
pulchella, Rom. .	= *Multicresis* .		*			
HETEROPORIDÆ.						
HETEROPORA.						
clavula, D'Orb.		*				
? *impar*, Lonsd.	= *Choristopetalum*		*			
The following species, given under the name of Ceriopora, I can only indicate their position provisionally:—						
CERIOPORA, Goldf.						
avellana, Mich. .		*				
cavernosa, Hag. .		*				
mammillosa, Rom. .	= *Multicresis* .	*				
Michelini, D'Orb. .	„ .	*				
polymorpha, D'Orb.		*	*			
Various:—						
Holostoma, Lonsd. .	= *Millepora dichotoma*, Mantell.				*	
Homeosolon, Lonsd.	= *Retepora flexuosa*, Mantell. Described by Lonsdale in Dixon's 'Geol. of Sussex.'					

the Upper Chalk, both in my own and in Miss Jelly's collection. The patches are very small, but are not frequent. The Rev. Thomas Hincks (l. c. p. 190), in giving its range in time says: 'French Cretaceous deposits, D'Orbigny.'

Locality.—Upper Chalk, Beachy Head (?).

Associated with this is the *Diastopora cretacea* (?) previously described.

Family SELANARIIDÆ, Busk.

'*Zoarium* free (?), orbicular or irregular, conical or depressed, convex on one side, and plane or concave on the other; composed of a single layer of cells, usually of two kinds, which open in the convex surface only.'—'Crag. Polyzoa,' p. 78.

In this family Mr. Busk places the fossil species of *Lunulites*, which range from the Crag to the Cretaceous epoch. As Mr. Busk gives full particulars of the family and genera, and a really good list—forty-four species—many of them *Lunulites*, I refer the student to it with pleasure, rather than give even an abridgement of his admirable notes ('Crag Polyzoa,' pp. 78–29).

LUNULITES CRETACEA (?), Defranc (? D'Orbigny). So Busk.

This is the only species known to me in the Chalk. Prof. Morris gives the following synonyms:—

= *L. urceolata*, Woodward; = *L. radiata*, Mantell.

Range from Lower Greensand to the Chalk.

As the species of Polyzoa in the tabular list on p. 174 are given by Mr. Newton in his 'Catalogue of Specimens in the School of Mines,' I make no apology for classifying them for the benefit of students. Pages in the Catalogue on which appear lists of Polyzoa, 6, 7, 39–49, 83–95.

PART II.

CLASSIFICATION OF CYCLOSTOMATOUS POLYZOA, ETC.

From the Silurian to the Cretaceous epochs only.

PROFESSOR MORRIS, F.G.S.

1843. In his 'Catalogue of British Fossils' Professor Morris adopted the following arrangement for the varied groups of Polyzoa found in our British rocks.

Fam. I. ESCHARIDÆ
„ II. CELLEPORIDÆ
„ III. RETEPORIDÆ
} = *Cheilostomata*, Busk.

„ IV. CRISIDÆ
„ V. MYRIAPORIDÆ
„ VI. TUBULIPORIDÆ
} = *Cyclostomata*, Busk.

1844. MR. FREDERICK M'COY.

In M'Coy's works on British Palæozoic Fossils,[1] 1844, the Class Polyzoa is divided into the following families:—

Escharidæ (with 17 genera). *Asterodiscidæ.*
Tubuliporidæ. *Halcyonellidæ.*
Myriaporidæ.

[1] *Synopsis of the Carb. Foss. of Ireland*, 1844, and *Brit. Palæozoic Foss.*

In the first family M'Coy placed Palæozoic genera—such as *Ptilodictya* and *Berenicea*, and in the third *Phyllopora* (Retepora), *Glauconome* = *Penneretepora*, D'Orb., *Acanthocladia*, King, and also *Fenestella*. With these were associated recent and fossil Polyzoa (not Palæozoic), belonging to Cheilostomatous genera, which were not at that time so distinguished by authors.

1850. PROF. WILLIAM KING.

In the 'Annals and Mag. of Nat. History,' and also in the 'Monograph of Permian Fossils,' Prof. King established the following family grouping for the inclusion of genera and species founded by himself or by others.

1849. FENESTELLIDÆ, King, 'Permian Fos.' p. 34.

Genus *Fenestella*, Miller (type).
,, *Ptylopora*, M'Coy.
,, *Polypora* ,,
,, *Synocladia*, King. 1849.
,, *Phyllopora* ,, ,,

1849. ELASMOPORIDÆ, King.

Genus *Elasmopora* = *Millepora cellulosa*, Linn. (type).

This family founded upon the above type is inadmissible as a Palæozoic representative group.

1849. THAMNISCIDÆ, King.

Genus *Thamniscus*, King.
? Syn. *Ichthyorachis* (pars), M'Coy.

Genus *Acanthocladia*, King.

As some of the family and also the generic names will be retained in this Report, it may be advisable to direct attention to a few particulars furnished by the author.

The sub-class in which the Permian Polyzoa are placed by Prof. King is the *Ciliobrachiate* of Farre, and the synonyms of the sub-class are given by him in the following order:—POLYZOA, J. V. Thompson; BRYOZOA, Ehrenberg; ZOOPHYTA ASCIDOIDA, Johnston; POLYPES TUNICIENS, Milne-Edwards. 'The divisions *Infundibulata* and *Hippocrepia* proposed by M. Gervais, as based chiefly on difference of habitat, whether marine or fresh-water, appear so divested of the necessary structural individuality, and of so little value compared with the orders already noticed, that in place of adopting them it seems a much safer plan to regard the Ciliobrachiates as resolvable into only one order, for which Ehrenberg's name *Bryozoa* may be very conveniently retained.' [1]

1846–1851. HAGENOW.

In the classification of the Cretaceous Polyzoa [2] by Friedrich V. Hagenow, the author adopts some of the genera previously established by Lamarck, Blainville, or Milne-Edwards, and also adds some few of his own. The genera adopted from Goldfuss and Lamouroux are redefined,

[1] King's *Permian Fossils*, p. 32.
[2] *Die Bryozeen der Mastrichter Kreid, &c.*, p. 51.

and many of the species of the *Ceriopora* of Goldfuss are redistributed. The following is his family grouping:—

A. TUBULIPORINA, Milne-Ed., with 9 genera
B. CERIOPORINA, Bronn „ 11 „
C. SALPINGINA, Hagenow „ 2 „
D. URCEOLATA . . „ 6 „

The last family contains nearly ninety species, and is largely the equivalent of the CHEILOSTOMATA, Busk, the first two families representing the CYCLOSTOMATA of Busk.

1852–1859. MR. GEORGE BUSK.

'Catalogue of Marine Polyzoa' ('Brit. Mus. Cat.' pt. i. and ii., 1852); 'Monograph of the Foss. Polyzoa of the Crag,' 1859.

One of the earliest and best classifications of the Polyzoa as a distinct group is that furnished by Mr. Busk in the second of these two works. As much, however, of the introduction and synoptical arrangements has more direct reference to a suborder that is very poorly represented in strata below and in the Cretaceous, I may be allowed to pass this over and confine my remarks to the second suborder, *Cyclostomata*, Busk. In the synoptical arrangement of this group Mr. Busk included genera belonging to the Mesozoic and Cainozoic epochs only; except in a few rare cases, there was no provision made for Palæozoic genera or species. In speaking of his own labours Mr. Busk says: 'Owing to the great comparative simplicity and uniformity of conformation in the individual cells, and the absence for the most part of adventitious organs such as ovicells and vibricular or avicularian organs, our principal reliance in the distinction of genera and species must be placed on the general form of the zoarium[1] and the mutual relation of the cells; but as in many cases these vary very greatly in different portions of one and the same zoarium, it often happens, more especially in fossil forms, that it is almost impossible to determine whether two apparently distinct things may not be referable to one and the same species. These observations apply more forcibly perhaps to *Pustulopora*, *Idmonea*, and *Hornera*, than to any other genera, but should be taken into account in several others also.'[2]

SYNOPTICAL ARRANGEMENT OF CYCLOSTOMATA.

§ I. Articulatæ s. radicatæ.

Family CRISIIDÆ, *Crisia*, *Crisidea*.

§ II. Inarticulatæ et adfixæ.

a. CELLULIS DISTINCTIS.

Family IDMONEIDÆ.

Genus *Hornera*.
„ *Terebellaria*.
„ *Cricopora*.
Genus *Cyrtopora*.
„ *Idmonea*.
„ *Pustulipora*.

Family TUBULIPORIDÆ.

Genus *Mesenteripora*.
„ *Tubulipora*.
Genus *Alecto*.

[1] 'Polyzoary,' Busk.

[2] *The Crag Polyzoa*, p. 90.

Family DIASTOPORIDÆ.

Genus *Diastopora*.	Genus *Discoporella*.
„ *Patinella*.	„ *Defrancia*.

b. CELLULIS INDISTINCTIS.

Family CERIOPORIDÆ.

Genus *Stellipora*.	Genus *Alveolaria*.
„ *Fungella*.	„ *Spiropora*.
„ *Heteropora*.	„ *Heteroporella*.
„ *Neuropora*.	

Family THEONOIDÆ.

Genus *Theonoa*.	Genus *Lopholepis*.
„ *Fascicularia*.	„ *Apseudesia*.[1]

Family FRONDIPORIDÆ.

Genus *Frondipora*.	Genus *Distichopora*.
„ *Truncatula*.	„ *Plethopora*.

To a large extent this synopsis has been accepted and followed by many leading naturalists in their arrangement of this group at least. Professor Reuss, in his various writings after the publication of the 'Crag Polyzoa,' adopted the arrangement with very slight modifications, and Dr. Manzoni followed Reuss, but Professor F. A. Roemer in his 'Polyparien des Norddeutschen Tertiär-Gebirges,'[2] divides the group thus:—

BRYOZOA, Ehrbg.

A. *Cellulata*, D'Orb.	=	*Cheilostomata*,	Busk.
B. *Tubuliporidæ*, M.-Ed.	=	*Cyclostomata*,	„
C. *Cerioporidæ*, D'Orb.	=	*Cyclostomata*,	„

Many of the genera in this arrangement are those founded by D'Orbigny, some few are still retained in our scientific literature, four only are founded by Professor Roemer.

a. CELLULATA.

Genus *Cycleschara*, Roemer.	Genus *Discoescharites*, Roemer.
„ *Porella*. „	

b. TUBULIPORIDÆ.

Genus *Escharites*.

It must not be supposed, because I pass over several authors who have laboured upon the Polyzoa, that I ignore their work. Although I am pretty familiar with the various classifications which have been issued since the publication of the 'Brit. Mus. Cat.' and the 'Crag Polyzoa,' many of the modifications that have been suggested apply more particularly to the Cheilostomata than to the Cyclostomata.

In the former suborder there are many points of superficial structure

[1] In my third Report this genus is spelt as in the Crag Polyzoa, Apsen*d*esia; I believe the proper spelling is with a *u* as above

[2] Cassel, Verlag von Theodor Fischer, 1863.

that would be naturally sought after by those whose desire it is to arrange the various genera in a natural sequence, but in the latter suborder there is but little variety except in the arrangement of the cells. In the later work of Mr. Busk,[1] in the writings of Professor Smitt, and in the 'Brit. Marine Polyzoa' (1880) of the Rev. Thomas Hincks, practically the original arrangement of the Cyclostomata is left untouched. In the work of Mr. Hincks there is a redistribution of genera in a very limited family arrangement; but the work deals manifestly with recent species, and with species found only in the British area.

In his Introduction to the Marine Polyzoa Mr. Hincks refers to the studies of Professor Smitt in the following terms: 'He (Smitt) has aimed at a genealogical classification, starting with the proposition that the variations of species follow the line of their development and may be in a great measure explained by it. The Polyzoa as compound animals offer great facilities for the study of the laws and causes of variation. The differentiation of the colony gives us a series of variations running from the early and simple states to the fully developed form which is the parallel of the series of differences amongst species. Thus the British species of *Crisia* represent the evolutionary stages of one and the same type, of which Smitt regards *Crisia geniculata*, Mil.-Ed., as the first and simplest. The forms of this genus he would arrange according to the law of their evolution in a series, the members of which, springing from a common origin, will hold each its evolutionary grade.'[2] This, on the whole, may be a sound working principle, though it may not be always applicable when investigating the Palæozoic Polyzoa. I have not the least doubt but that some of the *Graptolites* and some of the earliest types of Polyzoa had a common ancestral origin. I believe also that the uni- and multi-serial *Stomatopora* represent evolutionary stages of a more primitive type; but we are not able to show at what stage divergences or differentiation of the colony took place, for the simple reason that the simple and the compound colonies occupy the same horizon in the Lower Silurians of America. In this country we have only uniserial *Stomatopora* in the Wenlock Shales. We do not meet with multiserial *Stomatopora* until we reach the Lias.

One of the chief difficulties the systematist has to encounter in classifying the Fossil Polyzoa is this: On what characters in the *zoarium* shall divisions be based? If every variation of the *zoaria* is to be accepted, then there can be no limits set which shall be binding alike to all Palæontologists, for the *zoaria* of species vary greatly in different localities and in different countries. Then, again, if—as the old workers have done—we accept the fenestrule, its size, shape, or character, as an element to guide us in the structure of genera or species, we shall still be at fault, for in very many of the *Fenestella*, both in this country and in America, the fenestrule varies greatly, even in the same *zoarium*. There is, however, one element that may be safely relied on, and this I have chosen for my guidance—that is, the structure and the arrangement of the cells in the branch, or in the colony; all other characters, structural or superficial, are subordinate to this.

This principle has been adopted by Mr. Hincks in his arrangement of *Recent* Polyzoa, and admirable results have followed. I shall not there-

[1] *Brit. Mus. Cat.* pt. iii. Cyclostomata.
[2] *Brit. Mar. Polyzoa* (Hincks), vol. i. p. cxx.

fore be out of the pale of competent authority in thus seeking to extend the principle to Fossil Polyzoa. Before closing these remarks, however, I cannot help saying that to seek from the embryologist information that would help to dispel the cloud of doubt that surrounds the earlier history of the Palæozoic Polyzoa seems to be somewhat fanciful. Yet, in the latest researches of Dr. Jules Barrois on the Embryogeny of Cyclostomatous Polyzoa,[1] we are furnished with most important conclusions respecting the ancient group, as a result of researches on living forms. Barrois says: 'To conclude, we may put forward the hypothesis of the very ancient existence of a group of *Probryozoa*, composed of swimming organisms, free, and possibly analogous to the *Rotifera* (at least as regards the aspect and general arrangement of the body), and of which the few larvæ of *Entoprocta* that we have nowadays represent the sole survivors; from this group the existing *Bryozoa* are derived by adaptation to a new mode of life; certain larvæ have accustomed themselves to creep . . . upon their oral surface instead of swimming freely through the water; and hence the changes . . . which produce the Bryozoan form.'

A very cursory examination of the Synopsis of Primary Division of the Polyzoa,[2] formulated by Mr. Busk, will show that to a large extent these are founded upon recent types. The orders include both freshwater and marine species, and being originally devised by Dr. Allman for his classification of the Freshwater Polyzoa, the order *Gymnolemata* was necessarily extended for the inclusion of the whole of the Marine Polyzoa as well. The three suborders of Mr. Busk—*Cheilostomata*, *Cyclostomata*, and *Ctenostomata*—are founded upon certain peculiarities of the mouth of the cell. In the first of these divisions the orifice, or mouth of the cell, is subterminal and of less diameter than the area of the cell. In the second the cell is tubular, and the orifice or mouth is terminal; but as the third suborder has characters unknown to me in a fossil state, it may be conveniently dispensed with in this Report. The two divisions already alluded to are made to include the whole of the Fossil Polyzoa of the Crag, and also the whole of our Marine Polyzoa, British or foreign. At present I have no knowledge of any genus or species found within the European area at least, in either the Cainozoic or Mesozoic, that may not be included in the suborders of Mr. Busk, if slightly modified to meet a few rare cases. When, however, we get beyond the Mesozoic epoch, and pass into the Palæozoic, the cases are very different. It is here that we meet with types evidently belonging to the class Polyzoa, in which the cell is devoid of either terminal or subterminal stomata. In making a superficial examination of these we find that the true or normal cell is deeply set in the branch, stem, or frond, and what we see of the superficial orifice is not the mouth of the cell, but what may be fittingly called the vestibule; the true orifice is concealed. In many of the Palæozoic types the vestibule is very large, and generally filled with matrix. The genera in which the concealed stomata may be casually observed—for sections are required to show the distinct features—are species of *Ptilodictya*, *Arcanopora*, and *Rhabdomeson*. Besides the mere stomata there are certain peculiarities of the grouping of the cells, and of the interspaces between cell and cell, that would afford good diagnostic characters; but of themselves they are not of sufficient importance for my purpose. It is very

[1] *Ann. Mag. Nat. Hist.* Nov. 1882, p. 402.

[2] *Crag Polyzoa*, p. 9.

evident that types like these cannot be placed in existing suborders without doing violence to the original and generally accepted diagnosis of Busk, Smitt, and Hincks.

To prevent confusion and to meet the difficulty, I have founded a new suborder, which, following the example of Mr. Busk, is framed with distinct reference to the cell-mouth. We cannot afford to abandon our hold upon the two divisions so familiar to students of Recent Polyzoa; but in a synopsis of recent and fossil species and genera it is essential that every feature should be accurately described.

Since a joint paper of mine and Mr. Shrubsole's was read before the Geological Society,[1] an abstract of which was printed in the Proceedings of the Society, a valuable memoir of the American Palæozoic Bryozoa has been published by E. O. Ulrich[2] in the 'Journal of the Cincinnati Society of Natural History.' In this contribution a new suborder is proposed for the purpose of including groups some of which cannot possibly, for reasons presently to be explained, be included in this Report of Fossil Polyzoa. Mr. Ulrich says that his suborder TREPOSTOMATA 'is proposed for the reception of the majority of the Palæozoic and many of the more recent Bryozoa. The principal distinguishing features are—(1) that the *zoarium* is composed of slender fasciculate tubes, which do not (as in the case of the *Cyclostomata*) gradually enlarge as they approach the surface, but remain throughout nearly of the same diameter; and (2), that, at a certain point in the course of the tubes to the surface, they bend outward more or less abruptly, and *change* in character. Besides the following Palæozoic families, the *Cerioporidæ* should be referred to the TREPOSTOMATA.'[3]

The Palæozoic families included in this new suborder are *Ptilodictyonidæ*, Zittel emend. Ulrich; *Stictoporidæ*, Ulrich; *Monticuliporidæ*, Nicholson; *Fistuloporidæ*, Ulrich; and *Ceramoporidæ*, Ulrich. It is not now with me a question of priority, but a question of fitness. Accepting the diagnosis of Mr. Ulrich, which, for the things *he* includes in the new suborder, is very good, I ask, who that knows anything of recent Bryozoa or Polyzoa would be inclined to adopt the *Monticuliporidæ* as defined and limited by Professor Nicholson,[4] or even by Mr. Ulrich, as Polyzoa? As to the *Cerioporidæ*, if Busk's family is meant, only one genus in that family, *Stellipora*, could be placed, provisionally, in the suborder as defined by Mr. Ulrich. I have not the least wish to cast the slightest disparagement upon this piece of really good work, but having been forced to dissent from the classification of the Bryozoa of Mr. Ulrich, I will now give my reasons for doing so.

In a former admirable Report published by the British Association,[5] there is one entitled the 'Third Report on British Fossil Corals,' by Professor Duncan. At p. 128 the author says: 'Jules Haime, when investigating the Oolitic Polyzoa, classified forms without septa and with tabulæ, like *Chætetes* or *Monticulipora*, as Polyzoa, and the beautiful *Stelliporæ* were especially included.

'Now the question arises, are there any recent Polyzoa, whose soft parts have been examined, that have tabulæ? From our knowledge of the recent Polyzoa, it is unsafe to answer this in the affirmative. There is a fresh-water species which is said to have tabulæ, but the assertion

[1] June 21, 1882. [2] October 1882. [3] *Op. cit.* p. 151.
[4] Vide the genus *Monticulipora*.
[5] *Reports*, 1871, pp. 116–137. By P. Martin Duncan, F.R.S., F.G.S.

requires confirmation. The classification, then, of these forms amongst the Polyzoa must be deferred, and I propose to decide against it now.

'*Beaumontia* is distinguished by MM. Milne-Edwards and Jules Haime as follows :—"This genus is distinguished from all other Chætetinæ by the formation of its tabulæ, which are irregular or vesicular, and it thus resembles *Michelenia*, belonging to *Favositinæ*." The presence of septa belonging to three cycles is asserted by the same authors, and this fact must remove the genus quite out of the neighbourhood of septaless forms.

'The genera of the Chætetinæ were formerly *Chætetes*, *Monticulipora*, *Dania*, *Stellipora*, *Dekayia*, *Beaumontia*, and *Labechia*. It has been shown that *Stellipora*, *Dekayia*, and *Labechia* are subgenera of *Monticulipora*, that *Dania* cannot be separated from *Chætetes*, and that *Beaumontia* has no correct affinity with the others, and that it belongs to another family.

'The genera should stand thus :—

CHÆTETINÆ.

Chætetes.	Subgenus,	*Dania.*
Monticulipora.	,,	*Stellipora.*
	,,	*Dekayia.*
	,,	*Labechia.*

But the subgeneric names should be dropped.

'This result is interesting because it eliminates *Beaumontia*, and makes a compact series, the affinities of which are not Polyzoan, but which may be Alcyonarian or Hydrozoan.'

After the most careful study of species belonging to the several genera mentioned, and even after the study of the later investigations of Professor Lindstrom and Professor Nicholson, I cannot help but accept this early decision of Professor Duncan. I am not sufficiently versed in the necessary knowledge respecting the Actinozoa to assert anything about the Alcyonarian nature of the *Chætetinæ*. Professor Duncan classifies the *Alcyonaria*, in the same Report, p. 135, thus :—*Chætetes*, *Monticulipora*, *Dania*, *Stellipora*, *Labechea*, and he also gives a careful *résumé* of the opinions of Professor Agassiz (pp. 132–3) respecting the Hydrozoan characteristics of the same group.

There remains but little to add to the masterly way in which Professor Duncan (previous to the grouping of the Monticuliporidæ by Professor Nicholson) dealt with the question of the relationship which was supposed to exist between the *Chætetinæ* and the *Polyzoa*. Since that time several attempts have been made to revive the classification of Jules Haime already referred to by Professor Duncan, and the genus *Heteropora* has been often referred to as a probable link between the Polyzoa of the Mesozoic and the *Chætetinæ* of the Palæozoic epochs. The *Heteropora* of the Oolites and of the Cretaceous I have carefully studied, but so far as I am acquainted with this genus, even including those species of the Crag, I cannot decide in favour of those who believe that there is a remarkable affinity between the two groups. The *Heteropora* may well puzzle the most painstaking of students, and a positive decision, either one way or the other, is a difficult matter. Still I cannot help believing that the species of this genus have nearer affinities with Polyzoa than with either *Chætetes* or *Monticulipora*.

It is at this point that the classification of E. O. Ulrich fails to convince me. I acknowledge with pleasure the care with which the author

has approached his subject, and I shall not fail to accept several of his genera for my own labours, but whenever I do accept them there must be clear evidence that I am dealing with the deserted homes of polypides and not with the remains of Alcyonarians.

The following is the classification and family arrangement of the Palæozoic Bryozoa, with their included genera already referred to :—

Order GYMNOLEMATA, Allman.

Suborder CYCLOSTOMATA, Busk.

Family TUBULIPORIDÆ, Busk.

Stomatopora, Bronn. *Berenicea*, Lamx.
Proboscinna, Audouin. *Rapalonaria*, Ulrich.

Family THEONOIDÆ, Busk. *Scenellopora*, Ulrich.
" ENTALOPHORIDÆ, Reuss. *Mitoclema* "
" FENESTELLIDÆ, King.

Fenestella, Lonsdale. *Phyllopora*, King.
Polypora, M'Coy. *Archimedia*, Lesueur.
Septopora, Prout. *Lyropora*, Hall.[1]
Fenestralia, "

Family ACANTHOCLADIDÆ, Zittel. *Penniretopora*, D'Orb.
= *Glauconome*, Lonsdale.

Family ARTHRONEMIDÆ, Ulrich.

Arthronema, Ulrich. *Arthroclema*, Billings.

Suborder TREPTOSTOMATA, Ulrich.
Family PTILODICTYONIDÆ, Zittel.

Ptilodictya, Lonsdale *Dicranopora*, Ulrich.
Graptodictya, Ulrich. *Clathropora*, "
Arthropora, "

Family STICTOPORIDÆ, Ulrich.

Stictopora, Hall. *Cystodictya*, Ulrich.
Stictoporella, Ulrich. *Pachydictya*, "
Rhinodictya, " *Phyllodictya*, "
Phænopora, Hall.

Mr. Ulrich says in the last two families diaphragms (*tabulæ*) are often developed; and as the remaining three families, *Monticuliporidæ*, Nicholson, *Fistuliporidæ*, Ulrich, and *Ceramoporidæ*, have diaphragms (*tabulæ*) strongly developed, they cannot be admitted amongst the Polyzoa for reasons already given. The family *Ceramoporidæ* contains one genus, *Eridopora*, some of the species of which closely resemble our own Carboniferous *Ceramopora megastoma*, M'Coy, and Mr. M'Coy's genus *Fistulipora* (type *F. minor*) is in all probability only the mature growth of *C. megastoma*, M'Coy.[2]

[1] *Carinopora*, *Cryptopora*, Nich., *Ptilopora*, M'Coy, not examined, Ulrich.
[2] Mr. John Young, F.G.S., on *Fistulipora minor*, *Ann. Mag. Nat. Hist.* Dec. 1882, and Review of the Family *Diastoporidæ*, Vine, *Quart. Jour. Geo. Soc.* 1880, p. 356.

In the Suborder *Cheilostomata*, fam. *Membranoporidæ*, Busk, Mr. Ulrich places one genus only, ? *Palæschara*, Hall, and he remarks (*loc. cit.* p. 156): 'A few American Palæozoic genera of Bryozoa have been omitted from the above classification, because I have not yet been able to give them the attention required for a full elucidation of their characters and affinities.'

Through the kindness of Mr. J. M. Nickles, of Cincinnati, I have been furnished with specimens of a great many of the so-called Bryozoa of the Cincinnati group, and the drawings and descriptions of Mr. Ulrich will enable me to give details, and weave in genera in the classification of the whole of our Fossil Polyzoa.

For rather more elaborate details than I have been able to give in this report I have very great pleasure in referring the reader to the first chapter of 'The Genus *Monticulipora*,'[1] entitled 'The General History of the Genus,' and also Chapter III. for the statement of the views of Dr. Lindstrom (extract from 'Ann. Nat. Hist.' ser. iv. vol. xviii. p. 5 et seq.), and to Mr. Busk, Mr. A. W. Waters, and Prof. Nicholson on the genus and species of *Heteropora*.

Class Polyzoa.

= *Bryozoa*, Ehrenb. *Bryozoa* (pars) of American authors.
= *Bryozoa*, Reuss, Manzoni, Waters.

Order Gymnolemata, Allman.

I. Suborder Cheilostomata, Busk, Hincks.

'Orifice of the *zoœcium* closed by a movable opercular valve. Ova usually matured in external marsupia. Appendicular organs (avicularia and vibricula) frequently present.'

II. Suborder Cyclostomata, Busk, Hincks.

Zoœcia tubular, with a plain inoperculate orifice. Marsupia and appendicular organs wanting.

III. Suborder Cryptostomata, Vine.

Zoœcia tubular, sub-tubular, in section slightly angular. Orifice of cell surrounded by vestibule, concealed.

Family I. Stomatoporidæ.

Zoarium entirely adherent, simple or branched. *Zoœcia* arranged in a single series, or in several, which take a linear direction generally.

Genus 1. *Ascodictyon*, Nicholson and Etheridge, jun.[2]
2. *Stomatopora*, Bronn.[3]
Subgenus *Proboscina*, Smitt.

In the above grouping I have taken the simplest type of cell with which I am acquainted; and, as these genera are well represented in our own Wenlock Shales, which were evidently derived from an earlier series of rocks, they may be taken to represent the earliest adherent types of

[1] Prof. Nicholson, (Blackwood & Sons) Edinburgh and London, 1881.
[2] *Ann. Mag. Nat. Hist.* June 1877.
[3] For references, see 2nd and 3rd *Brit. Assoc. Reports on Foss. Polyzoa*, 1881–82.

Polyzoa. In America, *Stomatopora* and *Proboscina* are found in the Trenton rocks, and are also abundant in the 'Cincinnati group' of Ohio. With the above the *Rapalonaria* of Mr. Ulrich ('Journal of Cincin. Soc. Nat. History,' April 1879) may be temporarily placed. We have no *Rapalonaria*, however, in our British Palæozoic rocks.

ASCODICTYON, Nicholson and Eth. jun.

The genus *Ascodictyon* was originally founded by the authors for 'anomalous types' of fossils found in the Devonian rocks of America, and in the Carboniferous Shales of Scotland. By my own investigations I have been able to extend the range of some of the forms that were originally placed under the genus, to the Wenlock Shales at least. Subject to future correction, I think I have sufficient evidence to prove that *Stomatopora dissimilis*, Vine, is the mature form of *Ascodictyon radiciforme*, Vine; and because of this I associate this genus with the other two to form the family *Stomatoporidæ*.[1]

I have previously drawn attention to *Proboscina* ('Third Brit. Assoc. Rep. on Foss. Polyzoa,' 1882), and, although some authors regard it as of generic value, I think that it will be safer to allow the species that have heretofore been placed as *Proboscina* (fossil types at least) to fall under *Stomatopora*. (For remarks on recent species see Hincks' 'Brit. Marine Polyzoa,' vol. i. pp. 436–7). D'Orbigny's *Filesparsa incrassata* ('Pal. Fr.' loc. cit. p. 817) is in all probability, says Mr. Hincks, the same as Smitt's *Stomatopora incrassata* ('Brit. M. Poly.' p. 437).

Gen. Char.—'Organism composite, adherent; composed of calcareous cells or vesicles, the walls of which are perforated by microscopic foramina, but which possess no single large aperture. The cells united by short tubular necks, or disposed in clusters and connected with one another by hollow filamentous tubes.'—H. A. Nicholson and R. Etheridge, jun. (*op. cit.* p. 463).

Wenlock Shales.	*A. stellatum*; var. *siluriense*, Vine.	Shropshire.
"	*A. radiciforme*, Vine.	"
"	*A. filiforme*, Vine.	"
Middle Devonian.	*A. stellatum*, Nich. and Eth. jun.	Ontario.
"	*A. fusiforme*, " "	"
Carboniferous.	*A. radians*, " "	Scotland.
"	*A. stellatum*, " " or var.	" [2]

STOMATOPORA, Bronn.

(See Hincks and Busk for Synon. &c.)

Zoarium repent, adnate or free at the extremities, giving off erect processes (*Proboscina*); simple or branched; branches more or less ligulate. *Zoœcia* in great part immersed, arranged in a single series, or in several, which take a linear direction, or are very slightly divergent.'—Hincks, p. 424.

[1] Silurian Uniserial *Stomatoporæ* and *Ascodictya*, *Quart. Jour. Geo. Soc.*, Nov. 1881. Wenlock Polyzoa, ibid. Feb. 1882.

[2] Ibid.

Wenlock Shales.[1]	*S. dissimilis*, Vine. Below Wenlock Lim., Shropshire.
”	” var. *elongata*, Vine. ” ”
Wenlock Limestone.	” var. *compressa*, Vine. ” ”
Permian.	*S. Voigtiana*, King. Humbleton, Yorkshire.
Lias.	*S. montlivatiformis*, Vine. (See ‘Third Brit. Assoc. Rep. on Fos. Polyzoa,’ 1882.)
”	*S. antiqua*, Haime. ” ” ” ”
Inf. Oolite.	*S. dichotoma*, Lamx. ” ” ” ”
Gt. Oolite and Cornbrash.	*S. Waltoni*, Haime. ” ” ” ”
Cornbrash.	*S. dichotomoides*, D'Orb. ” ” ”
Cretaceous.	*S. gracilis*, Milne-Ed. (See 1st part present Report.)
”	*S. ramea*, Blainv. ” ” ”
”	*S. ramosa*, Michelin. ” ” ”
Infra-Oolite.	*S.* (*Proboscina*) *Jacquoti*, Haime. (‘Third Brit. Assoc. Rep.’)
Gt. Oolite.	” ” *Davidsoni*, Haime.[2] ” ”

I have examined specimens of the whole of the above, with the exception of King's species, which I give upon his authority.

Family II. TUBULIPORIDÆ.

Zoarium adherent, more or less free, flabellate, lobate or cylindrical. *Zoœcia* tubular, disposed in contiguous series. *Oœcium* an inflation of the surface of the zoarium at certain points, or a modified cell. (Hincks's ‘Brit. M. P.’ *pars.*)

Genus 3.	DIASTOPORELLA, Vine.	Type *D. consimilis*, Lonsd.
” 4.	DIASTOPORA, Lamx.	” *D. diluviana*, Lamx.
	” (biserial)	= Mesenteripora, pars.[3]
” 5.	TUBULIPORA, Lamarck.	Type *T. flabellaris*, Fabric.
” 6.	ENTALOPHORA, Lamx.	
” 7.	IDMONEA ”	

In any classification of Recent or Fossil Polyzoa, the grouping of suitable genera under this family name will be always difficult, and perhaps, to some, unsatisfactory. I have, however, followed very closely Mr. Hincks, but working as I am upon fossil species, with a pretty full knowledge of the recent, I have made a few alterations advisedly.

The genus *Diastoporella* is the nearest approach to Mesozoic *Diastopora* that we have in the Palæozoic rocks. It is rare in the Wenlock Shales—not so much so in the Wenlock Limestone, but I have obtained the best results from the study of a fine specimen presented to me by Professor Gustav Lindstrom, and upon this I found the present genus,

[1] In the Lower Silurian Series, America, there are many beautiful forms of *Stomatopora*, and *Proboscina* range from these lower rocks upwards. See Ulrich, *Am. Pal. Bryozoa.*

[2] In Mr. Walford's cabinet there are still many undescribed species which, if worked up, would increase the number and range.

[3] It may be well, by way of preventing a misconception, to refer to the genus *Terebellaria*. I cannot give it a place in the present classification, but having given an account of the development of the species in my ‘Third Brit. Assoc. Rep.’ 1882, I refer the student to that paper for further remarks.

which will be referred to again further on. In America, Mr. Ulrich's *Berenicea primitiva* (*op. cit.* p. 157, 'American Palæoz. Bryozoa'[1]), which he says is rare in the Cincinnati group, is much closer related to Mesozoic Diastopora (*Berenicea*) than anything we have. The cells of his *B. vesiculosa*, Ulrich, resemble some of the cells of Oolitic 'Mesenteripora,' some of the species of which I do not place with the Cyclostomata in this Report.

For the genus *Diastopora*—adherent forms—I take one of the species of Lamouroux, and also one for the biserial species that may be safely placed in the genus. For similar reasons, previously expressed by Mr. Hincks (*op. cit.* p. 443), I accept *Tubulipora*, Lamk., and allow it to follow in a natural sequence *Diastopora*; species are partially adherent and partly free. With regard to *Entalophora* it may be well to say a word. Mr. Hincks allows the genus to follow *Idmonea*, but I prefer that it should follow *Tubulipora* for the reason given by the author (p. 455), that in its young state *Entalophora* 'consists of an adnate tubular crust.' There are, however, two types of this genus ranging from the Silurian rocks to the present seas—the *Pustulopora* type of Busk and the *Spiropora* type—and I have not as yet been able to satisfy myself that the two had a common origin.

DIASTOPORELLA, Vine.

(See 'Brit. Assoc. Rep.' ii. 1881 = *D. consimilis* (*Aulopora*, Lonsd.))

Zoarium encrusting, irregular, rarely circular. *Zoœcia* tubular, elongate, contiguous, arranged in regular series; cell-mouths circular, with well-formed peristome, and occasionally slightly less than the diameter of the cell.

Wenlock Shales and Limestone,	*Diastoporella consimilis*, Lonsd.
Devonian Limestone (?) . .	*Diastoporella M'Coyii*, Salter. Padstow.

DIASTOPORA, Lamx.

= *Berenicea*, Lamx., Jules Haime, and authors (pars).

Zoarium adnate, usually discoid or flabellate, less commonly irregular in form. *Zoœcia* tubular, with an elliptical or sub-circular orifice, crowded, longitudinally arranged, partly immersed. *Oœcia* an inflation of cell or cells.

Lias . . .	*Diastopora*	*stomatoporoides*, Vine. (See paper as below[2]), and 'Brit. Assoc. Rep.' 1882.	
Inf. Oolite to Cornbrash (?)	*Diastopora*	*diluviana*, Lamx.	
Inf. & Gt. Oolite	,,	*ventricosa*, Vine.	
,,	,,	*oolitica*, ,,	
,,	,,	*cricopora*, ,,	
Great Oolite .	,,	*microstoma*, Haime.	
Gt. Oolite and Cornbrash .	,,	*Lucensis*, ,,	
Cretaceous .	,,	*Clavula*, D'Orb.	Greensand.
,, .	,,	*papyracea*, ,,	,,
,, .	,,	*Wetherelli*, Morris.	Chalk, Sussex.
,, .	,,	*cretacea* (new species.) See first part of present Report.	
,, . (?)	,,	*Sowerbii*, Lonsdale. *Ibid.*	

[1] *Cincinnati Soc. of Nat. Hist.* Oct. 1882.
[2] Further notes on the *Diastoporidæ*, Busk, *Jour. Geo. Soc.* Aug. 1881.

DIASTOPORA (Biserial)
= *Mesenteripora*, Blainv. and Busk.

Inf. Oolite . .	*Diastopora Lamourouxi*, Haime. ('Brit. Assoc. Rep.' on Fossil Polyzoa, pt. iii.)	
Inf. and Gt. Oolite	*Diastopora Waltoni*, Haime.	
" "	" *Wrightii*, "	
" "	" *scobinula*, Michelin.	
" "	" *Michelini*, Blainv.	
" "	" *lamellosa*, "	
Gt. Oolite . .	" *Endesana*, Haime.	
" . .	" *Davidsoni*, "	
Cretaceous . .	" *reticulata* (new species?) See first part of this Report.	

TUBULIPORA, Lamarck. (See Hincks, 'Brit. Mar. Polyzoa,' p. 443.)

Zoarium adnate, decumbent, or sub-erect, forming a variously-shaped expansion, either entire, lobate, or branched. *Zoœcia* tubular, partially free and ascending; arranged in divergent series.

Cretaceous . *Tubulipora Brongniartii*, Milne-Ed. = *Actinopora*.

ENTALOPHORA, Lamouroux. (Hincks, 'Brit. Mar. Polyzoa,' p. 455.)
= *Spiropora*. ('Brit. Assoc. Rep.' pt. iii. 1882.)

'*Zoarium* erect and ramose, rising from a more or less expanded base, composed of decumbent tubes; branches cylindrical. *Zoœcia* tubular, opening on all sides of the branches.'

Wenlock Shales .	*Entalophora regularis*, Vine.	= *Spiropora*.
" "	" *intermedia*, "	= "
Lias . . .	" *liassica*, Tate.	= "
Inf. and Gt. Oolite	" *straminea*, Phill.	
" "	" *cæspitosa*, Lamx.	
" "	" *Bagocensis*, D'Orb.	
" "	" *cellaroides*, Haime.	
" "	" *ramosissima*, D'Orb.	
Infra-Oolite .	" *cenomana*. ".[1]	
" .	" *costata*, D'Orb.	
" .	" *Meudonensis*, D'Orb.	
" .	" *Sarthacensis*, "	
" .	" *echinata*, Reuss.	= *Pustulopora* sp.
" .	" *pseudospiralis*, [Mich.	= *Peripora*, D'Orb.
Cretaceous . .	" *gracilis*, Goldf.	= *Ceriopora*, Goldf.
" . .	" *pustulosa*, "	
" . .	" *incerta* (new species). [(See first part of present Report.)	

IDMONEA, Lamouroux. ('Brit. Mar. Polyzoa,' p. 450.)

'*Zoarium* erect and ramose, or rarely adnate; branches usually triangular. *Zoœcia* tubular, disposed on the front of the branches,

[1] See list of species, *Third Brit. Assoc. Rep.* 1882.

ranging in parallel, transverse, or oblique rows on each side of a mesial line.'

Upper Chalk .	*Idmonea Comptoni*, Mantell.	
" " .	" *cretacea*, Milne-Ed.	
" " .	" *gradata*, Defranc.	

Family III. FENESTELLIDÆ. (Restricted.)

Zoarium forming large or small fenestrated or non-fenestrated expansions. *Zoœcia* arranged biserially in the branch, tubular, but slightly truncated at the distal extremity; orifice circular, opening on one side only. Branches united by dissepiments, or free.

Genus *Fenestella*, Miller & Lonsd.	Accepted type, *F. plebia*, M'Coy.
" *Ptilopora*, M'Coy.	" *P. pluma*, M'Coy.
" *Pinnatopora*, Vine.	" *P. elegans*, Young & Young.

In 1849 Professor King established this family for a very peculiar group of Palæozoic Polyzoa. 'Considering *Fenestella* as the type of the family, it is proposed,' says the author, 'to include in it all those reticulated genera agreeing with this genus in having the cellules planted on a basal plate composed of vertical capillary tubes, as first discovered by Mr. Lonsdale. Besides *Fenestella* this family embraces the *Ptilopora* and *Polypora* of M'Coy; also the genera *Synocladia* and *Phyllopora*.'[1]

It is very evident that if we relied upon the above diagnosis it would be impossible to accept King's family name for the restricted group which I have placed under this head. As *Fenestella* was taken by Professor King as the type, I prefer to use the name, and restrict the group to those species only in which the cells are arranged biserially in the branch.

The genus *Fenestella* has been so ably handled by Mr. G. W. Shrubsole,[2] and so recently, that I think it needless to enter upon any lengthy description here. Accepting Mr. Shrubsole's work, I will now give reasons for allowing this family to follow that of the *Tubuliporidæ*.

If we take any ordinary *Fenestella*, such as *F. plebeia*, M'Coy, we shall find that the branches bear two rows of cells, separated, apparently, by a median keel. A vertical section of the branch shows that the cells are arranged in a line, but that the proximal part of the cell is depressed, the distal portion rising upwards to the surface of the branch. A transverse section shows that the cells are alternately placed, that the keel is obliterated, and that the cells themselves are foraminated very similarly to the cells of recent *Crisia*, *Stomatopora*, or *Tubulipora*. There are also minute structures in these ancient cells, very similar to minute structures in recent species of Cyclostomatous Polyzoa. The capillary tubes referred to by Mr. Lonsdale are also a peculiar feature in the *zoarium* of *Fenestella*—that is, if I understand his reference aright—and are totally unlike any of the minute structures in *Retepora*, where, as Mr. Lonsdale says, 'capillary tubes are wanting.' In Mr. Busk's 'Cyclostomata' (p. 20), the following reference is made, for classificatory purposes, to *Fenestella*:—'Herr Kirchenpaur's genus *Retihornera* would, from his description, include some Escharidan or Cheilostomatous forms approaching *Reteporæ*; but among them his *R. dentata* and *plicata*

[1] *Permian Foss.* King, p. 34.
[2] *Quart. Jour. Geo. Soc.* May 1879, May 1880, May 1881. Three papers.

appear without doubt to be Cyclostomatous, and I have therefore ventured to appropriate his expressive appellation for the fenestrate forms of *Hornera*; not regarding it, however, as impossible that the fossil genus *Fenestella* may have a prior claim after all.'

Through the kindness of Miss Gatty I have been allowed to examine her collection of Polyzoa, amongst which is a beautiful specimen of *R. foliacea*, McGillivray. If this species may be taken as the type of *Retihornera*, none of the species of *Fenestella* known to me could be, even provisionally, associated with it. In some of the branches we have a triple and even a quadruple set of pores, and only in some rare cases are pores biserial in their arrangement. It may happen, however, when I come to treat of Tertiary fenestrate *Hornera*, that these may be associated with the more ancient *Phyllopora* in the family *Polyporidæ*; but even then I think that the group or groups should be kept distinct.

Mr. Shrubsole [1] has already pointed out the differences in the external characters of Silurian and Carboniferous *Fenestellæ*. It only remains for me to show that the structural differences are very slight indeed. The cells in all *Fenestellæ* are arranged bi-serially, and between the cells there are very delicate interspaces, the walls of the cells in the opposite sides of the branches being separate and distinct. Yet by means of this interspace the whole of the cells of the colony appear to be linked together. Have we here the passages through which the endosarc passed from cell to cell? If so, then the unity of the cells in the colony, and also the distinct surroundings of the cell by its own wall, and the purpose of the interspace, are easily explained.

In *Ptilopora*, M'Coy, the arrangement of the cells is very similar to that of *Fenestella*, but it is difficult to obtain specimens for making sections. I purposely keep the genus distinct, subject of course to future correction on account of its peculiar zoarial characters. Mr. Ulrich includes in his family *Fenestellidæ* the following genera:—

Fenestella, Lonsdale.	*Archimedia*, Lesueur.
Polypora, M'Coy.	*Lyropora*, Hall.
Septopora, Prout.	*Carinopora*, Nicholson.
Fenestralia ,,	*Cryptopora*, ,,
Phyllopora, King.	*Ptilopora*, M'Coy.

I have been compelled to found a new genus for Carboniferous species formerly included in *Glauconome*, Goldfuss. I should, however, have preferred to adopt the old names of King—*Acanthocladia*, or *Penniretepora*, D'Orb.—but neither of these genera conveys a just idea of the species which have been discovered since these names were formulated. *Acanthocladia* is a Permian fossil of the family *Thamniscidæ*, and the type of the genus, *A. anceps*, Schlotheim, has 'rows of cellules from three to six on the stems' (*op. cit.* p. 48), and the type of D'Orbigny's *Penniretepora* is *Glauconome disticha*, Lonsdale.

FENESTELLA. (Restricted.)

'*Zoarium* a calcareous reticulate expansion, either flat, conical, or cup-shaped, formed of slender bifurcating branches, poriferous on one face, connected by non-poriferous bars, forming an open network. *Zoœcia* immersed in the branches, and arranged in two longitudinal rows

[1] Brit. Upper Sil. Fenestellidæ, *Quart. Journ. Geo. Soc.* 1880, p. 242.

(divided) by a central keel on which are often prominences. Cell-mouth small, circular and prominent when preserved.'—G. W. Shrubsole.

Upper Silurian .	*Fenestella rigidula*, M'Coy.
"	" *reteporata*, Shrubsole.
"	" *lineata* "
"	" *intermedia*[1] (a passage form).
Carboniferous .	" *plebeia*, M'Coy. (Synonyms below.[2])
"	" *crassa*, "
"	" *polyporata*, Phill.
"	" *nodulosa*, "
"	" *tuberculocarinata*, Eth. jun.
"	" *membranacea*, "
"	" *Halkinensis*, Shrubsole.[3]
Permian . .	" *retiformis*, Schlotheim.

PTILOPORA, M'Coy.

(See 'Brit. Assoc. Rep.' Foss. Polyzoa, No. 1, 1880.)

We know but little of this genus, except that the zoarial characters are different from those of *Fenestella*. There is a feather-like arrangement in the *zoarium*, a central stem giving off lateral branches, which are connected by dissepiments having oval fenestrules. The branches, however, rarely bifurcate.

Carb. Limestone .	*Ptilopora pluma*, M'Coy (type).
	" *Phillipsii*, Vine. Castleton, Derbysh.

PINNATOPORA, n. gen.

Zoarium pinnated; with secondary branches, likewise pinnated; but rarely fenestrated by inosculation of pinnæ. *Zoœcia* tubular, arranged biserially, originating immediately beneath, or in a line with, the keel. *Carina* feebly developed in some, well developed in other species, ornamented with the bases of spines, or plain; no secondary pores. *Oœcia* (?) an inflated cell. (For figure see p. 192.)

Carboniferous .	*Pinnatopora bipinnata*, Phillips = *Glauconome* of authors.
?	" *gracilis*, M'Coy.
?	" *grandis* "
?	" *pulcherrima* "
	" *elegans*, Young and Young. = *Glauconome*, Y. and Y.
	" *aspera*, Young and Young.
	" *flexicarinata* "
	" *retroflexa* "
	" *robusta* "
	" *laxa* " ? = *G. elegantula*, Eth. jun.

[1] This name had been previously adopted by Mr. Prout for an American Carboniferous species of *Fenestella*, closely related to *F. Milleri*, Lonsd.

[2] For synonyms see G. W. Shrubsole on 'Carb. Fenestellidæ' (*op. cit.*)

[3] There are still some few Carboniferous *Fenestellæ* left which may ultimately merit specific distinction. At present I cannot include in this list more species than those already given.

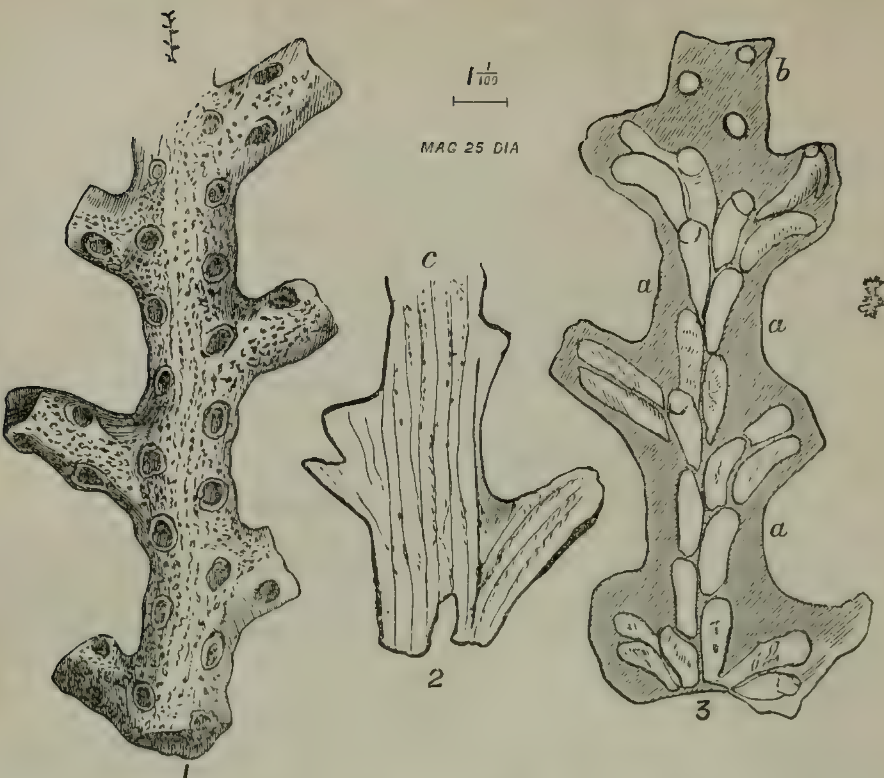


FIG. 1.—*Pinnatopora elegans*, Young and Young. Carb. Limst. Hairmyres, Scotland.

1. Typical external features of species. 2. Foraminated reverse.
3. Transparent section: typical structure of the genus.

Family IV. DIPLOPORIDÆ.

Zoarium fenestrated, or partly free and fenestrated. *Zoœcia* arranged biserially in the branches, opening on one side only. Supplementary *pores*, or *foramina*, in all the species of the various genera, but in one group the *foramina* are found on the reverse also.

General Remarks on the Family.—In the present Report I can only indicate the place that the family should occupy in this classification. I have made a careful analysis of the generic and specific characters of the whole of the carboniferous group of Polyzoa that may ultimately find a fitting resting-place here. In 1873, Mr. Robert Etheridge, jun., described[1] a 'peculiar polyzoon,' under the name of *Synocladia carbonaria*, R. Eth. jun., taking King's genus for the placement of the species. Ultimately, in the descriptive part of 'Explanation of Sheet 23,'[2] p. 102, Mr. Etheridge places the Scotch specimen as a variety only of *Synocladia biserialis*, Swallow; var. *Carbonaria*, Eth. jun. In 1858, details of Swallow's species were published ('Trans. St. Louis Acad.' vol. i. p. 179), and in 1873, Mr. Meek referred *Septopora cestriensis*, Prout,[3] to *Synocladia*

[1] *Annals & Mag. Nat. Hist.* [2] *Geological Survey of Scotland.*
[3] 'Descriptions of New Species of Bryozoa,' *Trans. St. Louis Acad. of Sci.* Third Series, 1859.

—'a form which appears to differ from typical species of *Synocladia* by having from one to four rows of cell-apertures on the dissepiment sinstead of two.' Mr. Hiram A. Prout, neither in his description of the generic character of *Septopora*, nor in the species which he places in the genus, says anything about supplementary pores; yet, in comparing specimens of Mr. Etheridge's *Synocladia carbonaria* with the beautiful figures of Prout, it appears to me that the 'medallion face,' with its irregular lines of pores on the dissepiments, only represents the full features now known to exist in carboniferous species (supplementary pores) which were only known as 'gemmuliferous vesicles' when King described his Permian *Synocladia*. If, therefore, some of my American friends can examine Prout's species, or fragments of the same, this matter may be set at rest, and in all probability the Scotch Carboniferous *Synocladia* (?), already described by Mr. Etheridge and Mr. John Young, may be placed here. Waiting, therefore, further investigations, I will place, temporarily at least, the species at present known to exist in our British rocks.

Carboniferous, *Septopora*, (?) *carbonaria*, Eth. jun.
„ „ *scotica*, Young & Young.
„ „ *fenestelliformis*, J. Young.[1]

Whatever generic name the above species may bear in the future, I do not think they can be more fittingly placed than in the present family. There is, however, an element of doubt in the adoption of *Septopora*, and, but that the Messrs. Young have associated the name *Diplopora* with an altogether different species, I would suggest that *Septopora* should be replaced by *Diplopora*.

There are two or three more species that may be placed in the family, although the secondary pores are differently placed. They are:—

Glauconome (*Diplopora*) *marginalis*, Young & Young.
„ (*Acanthopora*) *stellipora* „
Actinostoma fenestrata „

The element of structure in *Acanthopora* and *Actinostoma* are the rayed orifices of the *Zoœcia*. A feature so prominent as this ought not to be under-estimated, but in the present state of our knowledge respecting the operculate or non-operculate coverings of the cells of palæozoic species of Polyzoa, it would, perhaps, be unwise to fix any particular types for these genera.

As subgeneric forms of the Fenestellidæ, the following peculiarly distinct types may in the future be favourably considered. At present, it is impossible to localise the species in this classification on account of fictitious, or insufficiently described, characters.

Genus, *Fenestralia*, Hiram A. Prout. Carb. Bryozoa.[2]
„ *Synocladia*, King. Permian species.

I am also unable at present to give a resting-place to Mr. Robert Etheridge's type species,

Goniocladia cellulifera.

[1] This is a peculiar species, and I am not sure that I am right in placing it here. It is fully described by Mr. John Young, *Proc. Nat. Hist. Soc. Glasgow*, January 25, 1881.

[2] *Transactions of St. Louis Acad. of Sci.* First of a Series on 'Carboniferous Bryozoa.' H. A. Prout. Vol. I. 1858.

Family V. POLYPORIDÆ.

Zoarium forming large or small fenestrated expansions. *Zoœcia* contiguous; with three rows and upwards of cell-openings in a row, on one side only. *Branches* united by dissepiments or by anastomosis.

Genus	*Polypora*, M'Coy.	Type	*P. dendroides*, M'Coy.
,,	*Phyllopora*, King.	,,	*P. Ehrenbergii*, Geinitz.

These two genera differ in the anastomosis of the branches, but in the arrangement of the cells in the branch there is a striking similarity between them. The *Fenestella intermedia*, Shrubsole, of the Silurian rocks, appears to be a kind of connecting link between the two groups, Fenestellidæ and Polyporidæ. The *F. intermedia* occurs in the Niagara rocks at Lockport, as well as in our own Wenlock series. The branches are occupied alternately by two and by three rows of cells, so that it is rather a difficult matter to decide to which family group it should be referred.

In a recent paper on *Phyllopora* ('Quart. Journ. Geo. Soc.' vol. xxxviii. p. 347) Mr. Shrubsole says that from the Devonian rocks (Palæozoic Foss.) Phillips figures the *Phyllopora* with circular fenestræ as *Retepora prisca*; that with lozenge-shaped fenestræ as *Fenestella anthritica*, and that with square fenestræ as *Gorgonia ripisteria*. As might be expected, there is considerable confusion of species in Phillips's delineation of the Devonian Polyzoa; two or more varieties are included under one head (*op. cit.* p. 384). This is to be regretted, but, as Mr. Shrubsole says, it is almost impossible to make a revision of Devonian Polyzoa on account of the difficulty of obtaining material for the purpose. We are indebted to Professor Nicholson for much valuable information in his descriptions of Polyzoa in his paper on 'New Devonian Fossils' in the 'Geological Magazine,' 1874. The various species of Polyzoa described by Nicholson are from the 'Devonian formation of Canada West.'

POLYPORA, M'Coy.

Zoarium a delicate or robust, reticulated calcareous expansion; branches round, connected by thin dissepiments. *Zoœcia* contiguous, with from three to five rows of cell-openings in a branch, on one side only; marginal cells occasionally projecting.

Carboniferous .	*Polypora*	*dendroides*, M'Coy.
	,,	*tuberculata*, Prout.
	,,	*laxa*, Phill.

PHYLLOPORA, King ('Permian Fossils,' p. 40).

Zoarium consisting of an infundibuliform or foliaceous expansion. *Zoœcia* on one side only, and occupying the whole surface of the branch; cells contiguous. Branches united by anastomosis, and not by dissepiments.

Lower Silurian .	*Phyllopora*	
Upper Silurian .	,,	sp.
Devonian . .	,,	*prisca*, Phillips.
Carboniferous .	,,	
Permian . .	,,	*Ehrenbergii*, Geinitz.
,,	,,	*multipora*, Shrubsole.

Family VI. Horneridæ.

In founding this family Mr. Hincks says only: '*Zoœcia* opening on one side only of a ramose zoarium never adnate and repent.' ('Brit. Mar. Polyzoa,' vol. i. p. 467.)

Excepting the *Siphodictyum* of Lonsdale, *Hornera*, as known to us in the Crags, is not represented—typically—below the Tertiaries. I cannot therefore accept the types of the recent family for Mesozoic or Palæozoic genera.

Greensand . *Siphodictyum gracile*, Lonsdale = *Hornera* (?).

Family VII. Thamniscidæ.

Zoarium forming free dichotomising branches, or pinnated fronds. *Zoœcia* on one side only, with from three to five (or more ?) rows of cell-openings in a branch, occasionally having a smaller opening above or below the peristome of the cell (base of spine ?).[1]

Genus *Thamniscus*, King.
" *Acanthocladia*, " ? = *Ichthyorachis*, M'Coy.

These genera, which have heretofore been loosely defined and as loosely accepted by some Palæontologists, are now restricted. The genus *Thamniscus* was founded by Professor King, and though he did not read aright all the characters which his specimens afforded for a complete study, still he gave a good general estimate of its varied features. Professor King says ('Perm. Foss.' p. 44): 'I formerly placed the type of this genus in Lamouroux's *Hornera*; but it is evident from Mr. Lonsdale's observations that this was an erroneous collocation.' The type—*Thamniscus dubius*, Schlotheim—is very well described by King, and also well figured, but it was not possible, at the time he wrote, to clear up satisfactorily all the points raised by him. In the text, and also in the figures (pl. V. fig. 10), Professor King indicates that *Thamniscus* simulates the character of *Synocladia*; this was clearly an error, as has been pointed out by Mr. G. W. Shrubsole in his paper on '*Thamniscus*: Permian, Carboniferous, and Silurian' ('Quart. Journ. Geo. Soc.' vol. xxxviii. p. 341). Of the other genus I may say that the typical *Acanthocladia*, King, and *Ichthyorachis*, M'Coy, appear to cover the same ground; but it is impossible to include in the genus species so different in their structural characters as *Glauconome pluma*, Phill., and *G. bipinnata*, Phill. I accept the diagnosis of *Acanthocladia anceps*, Schlot., and take it as the generic type.

Thamniscus, King.

Restricted by G. W. Shrubsole (*op. cit.* p. 343).

Zoarium multiform. Branches free, round, frequently and regularly bifurcating; more or less in one plane. *Zoœcia* on one side. Cells immersed, round, arranged in oblique lines. Reverse foraminated.

Silurian	*Thamniscus*	*crassa*, Lonsdale	= *Hornera*, Lonsd.
"	"	*delicatula*, Vine	= *Hornera*, ? Vine.
Carbonif.	"	*rankinei*, Young & Young.	
"	"	*carbonaria*, Vine.	
Permian	"	*dubius*, King.	

[1] Foramina on the reverse in one species.

ACANTHOCLADIA, King = ? ICHTHYORACHIS, M'Coy.
(A. THAMNISCIDÆ, King.)

Zoarium bilaterally branched more or less in one plane, rarely bifurcating. In his description of *A. anceps*, King says: 'Rows of cellules from three to six on the stem.'

M'Coy's definition of *Ichthyorachis* is as follows :—

'A straight central stem, having on each side a row of short simple branches or pinnæ, all in the same plane, obverse rounded, without keel; each bearing several rows of small prominent oval pores, arranged in quincunx, reverse smooth or finely striated.'—'Carb. Foss.,' pl. XXIX. fig. 8.

The *Ichthyorachis* as described by M'Coy is peculiarly a Carboniferous type. I have met with it in the Carboniferous strata of Derbyshire, and I prefer that the name should remain, at least for the present.

Carboniferous	*Ichthyorachis Newenhami*, M'Coy.
Permian	*Acanthocladia anceps*, Schlot. (and King).

Family VIII. HETEROPORIDÆ.

Zoarium cylindrical or multiform, undivided or branched; surface even, furnished with openings of two kinds—the proper *zoœcia*, and interzoœcial openings; occasionally encrusting.

Genus *Heteropora*, Blainville.
,, *Hyphasmapora*, R. Etheridge, jun.

The '*Ceriopora*' of the Carboniferous epoch may be conveniently included in the genus *Heteropora*. *Hyphasmapora*, on account of certain structural peculiarities, must, I think, be kept as a distinct type.

Carboniferous	*Heteropora*	*interporosa*, Phill. = *Ceriopora*, Phill.		
,,	,,	*similis*, ,, = ,, ,,		
,,	*Hyphasmapora*	*Buskii*, R. Eth. Jun.		
Jurassic	,,	*conifera*, Lamx. (multiform type).		
,,	,,	*pustulosa*, Michelin, ranging into the 'Crag.'		
,,	,,	*reticulata*, Haime.		
Cretaceous	,,	*dichotoma*, Goldf. (See first part of present Report).		
,,	,,	*reticulata*, ? Busk	,,	,,
,,	,,	sp.	,,	,,
,,	,,	*tenera*, Hagenow	,,	,,

Suborder CRYPTOSTOMATA.

Zoœcia tubular, subtubular, in section (occasionally) slightly angular. *Orifice* of cell surrounded by vestibule, concealed.

I have already pointed out the peculiarities of this suborder when speaking of the one proposed by Mr. Ulrich. It will be well, therefore, to deal very fully with the genera and species that I propose to assign to this division of Palæozoic Polyzoa.

Mr. Ulrich in his classification of 'American Palæozoic Bryozoa' (*op. cit.* p. 151) proposes two family names for the grouping of species which have heretofore been loosely placed in one group only. The first is the

family PTILODICTYONIDÆ, Zittel emend. Ulrich; the second is STICTOPORIDÆ, Ulrich.

In the first of these families Mr. Ulrich places the following genera:—

1. *Ptilodictya*, Lonsdale.
2. *Graptodictya*, Ulrich.
3. *Arthropora*, Ulrich.
4. *Dicranopora*, ,,
5. *Clathropora*, Hall.

As *Ptilodictya*, Lonsdale, is taken as the type of this family, I shall make no apology for working out the structural characters of one, at least, of the forms upon which Lonsdale founded his genus.

1839. PTILODICTYA, nov. gen. (Lonsd.).

Derivation—πτίλον *pluma*, δίκτυον *rete.*

'Thin elongated expansions, having on each surface small quadrangular cells, not convex, which penetrate the coral obliquely, and are arranged, with respect to the surface, along the middle of the specimen, parallel to the elongated direction of the coral, but in the sides obliquely from it. Surface a very thin calcareous crust, traversed by slightly raised ridges, marking the boundary of the cells; towards the margins the crust thickens; the indications of the cells are less distinct, and at the edges are invisible, but cells are traceable close to the margin where the crust has been removed; opening of the cells small, transversely oval? No indication of a central partition parallel to the surface.'—'Silurian Syst.' p. 675, pl. XV.

Ptilodictya lanceolata, Lonsd. p. 675, fig. 11 to 11 *c*.

'Small fragments of probably young specimens of this species are occasionally found in the slabs of Wenlock Limestone. One of them is represented in pl. XV., fig. 11 *b*, 11 *c*.'—Lonsdale.

PTILODICTYA LONSDALEI, Vine.

Notes on the Polyzoa of the Wenlock Shales, &c., 'Quart. Jour. Geo. Soc.' Feb. 1882; Second Brit. Assoc. Report on Foss. Polyzoa, mihi, 1881, for information on the genus generally.

I have already described, under the name *Ptilodictya Lonsdalei*, some of the 'young specimens' referred to by Lonsdale. In that description I spoke of certain peculiar structures in the species (p. 66) with a promise that 'I should return to their discussion at some future time when other investigations were completed.' I now redeem the promise, in the hope that other Palæontologists will examine the species in their own localities, and compare them with these type specimens of Lonsdale.

I. Superficial characters of *Ptilodictya Lonsdalei*, Vine. If we take a number of the fragments of this species, which we shall find rather abundantly distributed in the Wenlock Shales, and submit them to a tolerable heat in the fire, plunging them immediately after into water, we shall soon get rid of the 'crust,' and some peculiar structures will be revealed. The 'small quadrangular cells' referred to by Lonsdale will be seen to perfection, and according as the preservation of the *zoarium* is calcareous or ferruginous, the walls will be either of a white or of a dark brown colour. The rows of cells in a longitudinal direction are separated by dividing ridges, or by slightly raised ridges also referred to by

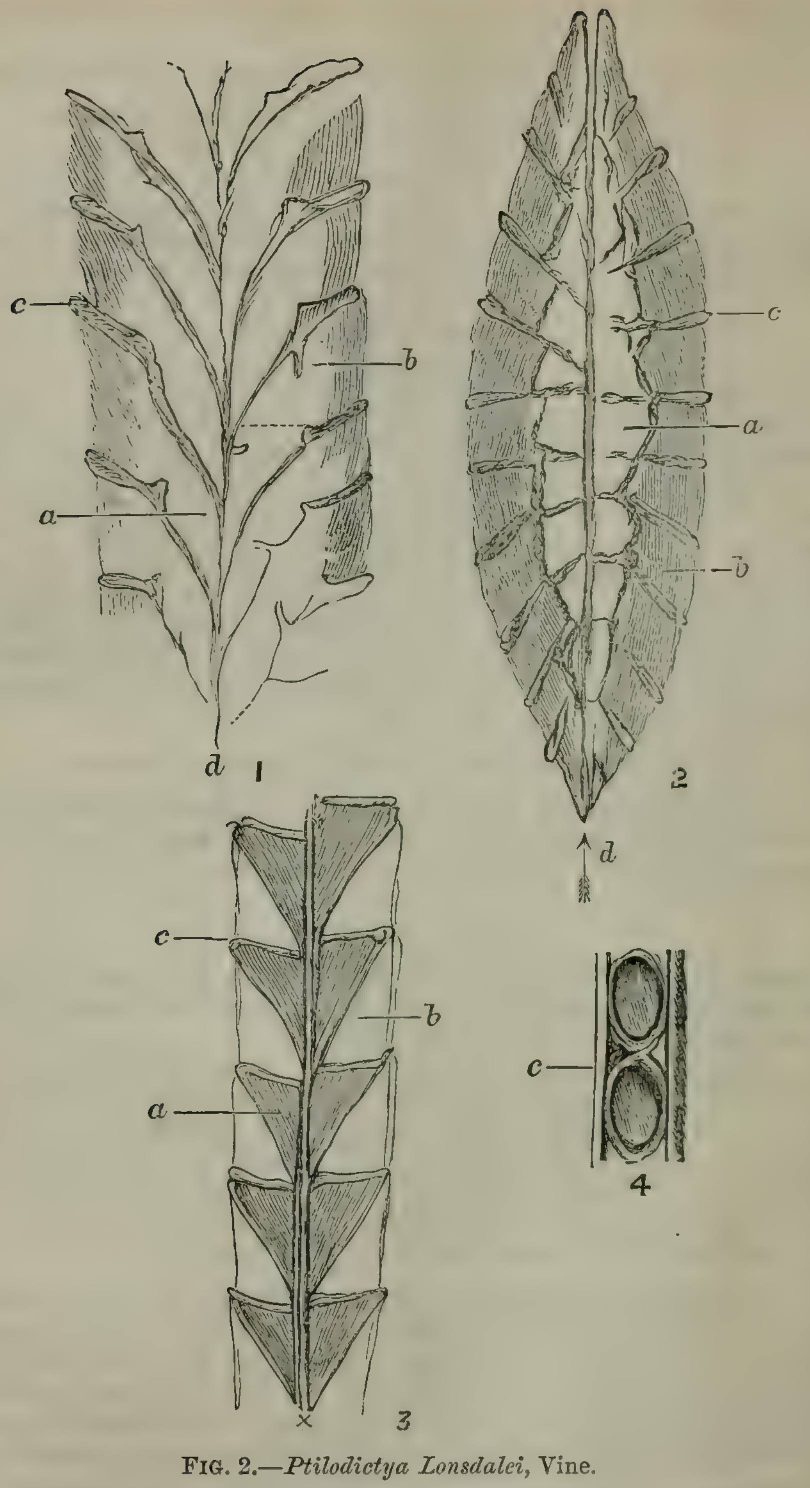


FIG. 2.—*Ptilodictya Lonsdalei*, Vine.

1. Longitudinal section, transparent. 2. Transverse section, transparent.
3. Longitudinal section, opaque.
4. Two cells with their adjacent bars, from a charred specimen, opaque.

The letters are the same in all the figures. *a*. The true cells. *b*. The vestibule of the cell. *c*. Intervening bars. *d*. Imaginary axis.

(Drawn by aid of camera lucida, magnified about 40 diameters.)

Lonsdale, narrow and compact in the central portion of the *zoarium*, rather wider and widely separated as the margin is reached. Within the 'ridges' or 'bars,' longitudinally, the cells are separated from each other by much thinner walls, and the apparently quadrangular character is now seen to be oval, but two oval cells touching each other at their proximal and distal extremities leave small angular spaces at the base, laterally, of each cell, p. 198, fig. 2, No. 4. This angular portion is perforated, consequently each oval cell orifice is seen to be surrounded by four perforated angular spaces, or, in other words, the 'quadrangular cells' are really oval orifices in outline, with the angular corners perforated; and rows of these are separated by the raised ridges already referred to.

II. *Zoarium* in section. A transverse section of the *zoarium* will show other points of structure referred to briefly by Lonsdale (p. 198, fig. 2, No. 2). We now find that the zoarium is raised in the middle, thinning out wedge-like towards the margins. In the centre the cells are perpendicular on each side of, what it will be convenient to call, the axial region. The cells on the right and left of the middle cells are slightly bent towards the right and left borders, and the angle of this bending of the cell decreases as the margin is approached. This shows the cause of that obliquity in the direction of the cells on either side of the central row, noticed by Lonsdale in the diagnosis of the genus *Ptilodictya*. He also observes that the 'cells penetrate the coral obliquely.' Superficially examined this appears to be the fact, but the extreme outer portion of the surrounding 'cell' orifice is not the true orifice of the cell; it is only the vestibule (p. 198, fig. 2, No. 2, *b*). The true orifice is deeper down, and the area of the cell is comparatively small (ibid. *a*) when compared with the area of the vestibule. This will be better seen when I describe the longitudinal section. If a tangential section of *Ptilodictya* is made, we find crossing each area a bar, and at first sight this seems to be the homologue of the 'tabulæ' referred to by Professor Nicholson in his diagnosis of *Heterodictya*. They are not 'tabulæ' in *P. Lonsdalei*, but they are sections of the cells which are reached at different depths, and they look, especially in transparent sections, very much like tabulæ.

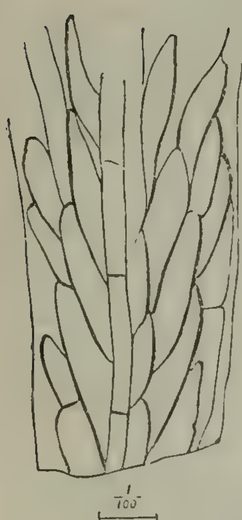
III. Longitudinal sections. These I have made and studied very carefully, and some of my sections reach the cells at different depths. If the student will refer to fig. 2, No. 3, p. 198, a good general idea of the cell and vestibule may be obtained. In this drawing I have given the outline of ten cells (drawn from an opaque section), five on each side of the axial region, but the axis as shown in the drawing is never found so sharp in section as it appears to be in the figure. Here the cells are angular and sub-opposite, so that two cells are almost triangular; the base of the triangle is the true orifices, and the apex is the proximal extremities of the cells, and the spaces left vacant, on either side, at the distal portion of the cells are the vestibules.[1]

IV. The vestibules. In the transverse section (p. 198, fig. 2, No. 2) of the *zoarium* of *Ptilodictya*, in fig. 2*b*, I have shaded the vestibules, while the cells are left white. The bars which separate the rows of cells are more deeply shaded, and when viewed in this aspect they appear to be club-like, decreasing in thickness as their extremities reach the cell. In some

[1] In thus alluding to the triangular character of the two cells, the student will understand my references better if the figures be reversed.

respects these 'club-like' partitions resemble the 'spiniform' processes described as 'Spiniform Corallites'[1] by Professor Nicholson, but they have nothing of the character, as will be presently seen, of corallite structure. On the surfaces of the *zoarium* and in the transverse sections these bars are prominent characteristics of the *Ptilodictya* of the Wenlock series of rocks at least, and, in a modified form, the bars in the *Sulcoretepora* of the Carboniferous rocks closely resemble them, but in none of the sections of the *Monticuliporidæ* given by Nicholson, or made by myself, are there any structures with which I can compare them. They appear to me to be unique both in character and function; neither do they resemble any partitions known to me in Cyclostomatous Polyzoa, recent or fossil.

V. Development of the *zoarium* of *Ptilodictya*. In one of Mr. Ulrich's earlier papers,[2] the author describes and figures two remarkable and



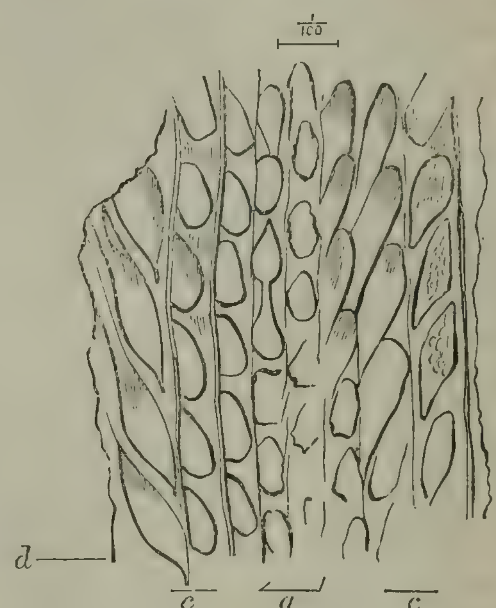


FIG. 3.—*Ptilodictya Lonsdalei*, Vine.

1. Young specimen just above the base (section). 2. Section of young specimen, having eight rows of cells; two (*a*) central, and three (*c*, *c*) lateral on each side. *d*. 'Non-poriferous margins.'

minute fossils, which he named *Crateripora*. In his paper on 'American Palæozoic Bryozoa' (*op. cit.* p. 151) Mr. Ulrich refers to *Crateripora* as being the 'attached bases of *Ptilodictyonidæ*.' These Crateripora form expansions upon foreign bodies, in the centres of which are small cup-like depressions. They are, as Mr. Ulrich says, the bases or rootlike portions of *Ptilodictya*, and though not common in the Wenlock Shales, I have several of them in my possession. Sometimes they are found upon corals, sometimes upon the *zoarium* of *Ptilodictya* itself; they are small disks, and at this early stage they have none of the after-characters of

[1] *The Genus Monticulipora*, p. 45.
[2] *Journal of the Cincinnati Soc. Nat. Hist.* April, 1879.

the genus. Above the base the stem for a slight distance appears to be delicately fluted, and at about one and a half lines from the base the fluted portion begins to obtain the normal character, and at about two or two and a half lines the normal character of the *zoarium* is reached; and at this stage I give details of structure which repeats itself in the after-development of the *zoarium* (p. 200, fig. 3, No. 1). The breadth at this particular point varies from about $\frac{1}{32}$ to $\frac{1}{25}$ of an inch.

At a very early stage in the development two cells form the central division of the *zoarium*, and from these lateral cells, obliquely on opposite sides, are thrown off, and beyond these there is what I will call, for the want of a better term, the virgin margin: that is a margin partaking of the same virgin substance which forms the base and early basal development. At this stage there are only two, and then four cells, near to and just above the base. Because of the heterogeneous character of the specimens, it is impossible to make out how or in what manner the cells are developed; consequently I have to resort to other transparent specimens for this information, and, to make my meaning more clear to the student of recent Polyzoa, I will describe briefly the process of development of the cells in the common *Crisia*, which can be easily verified by observation. Immediately above the flexible joint in *Crisia denticulata*,[1] there are two cells, which expand in a right and left hand direction, which form the base of the branch, and within the angle formed by and near to the base of these cells the two immediately above originate, and so on throughout the whole development of the branch, a new flexible joint originating in a kind of bastard cell, laterally or from the centre. In *C. cornuta* a delicate cænicium is seen to cover the lines of cells, and within this dermal covering the cells of this species originate. In the younger portions of the zoarium of *Ptilodictya*, that is towards the margins, the bars already referred to are not solid (p. 200, fig. 3, No. 2, *c c*) until after a certain stage is passed. Here we find that the new cell originates within the bar, a portion of the previously formed bar which is a kind of dermal covering; and as other cells are developed towards the margin, the bars, or rather walls, of the cells on the inner or more central portion of the zoarium become solidified. There are no bars on the outer portion of the zoarium.

VI. The 'laminar axis' of *Ptilodictya*. In all my palæontological labours I have been extremely anxious to do justice to previous authors, and I have never, so far as I am aware, either in these reports or in my other writings, taken advantage of other people's work without acknowledging its source. At times this desire to bow to authority has led me into error, which it may be well now to refer to. In my second 'Brit. Assoc. Report on Fossil Polyzoa,' 1881, like many other authors, I adopted M'Coy's diagnosis of the genus *Ptilodictya* instead of that of Lonsdale. In M'Coy's definition he refers to species having 'a thin, laminar, flattened, concentrically wrinkled central axis.' In consequence of this I referred to the 'axis' always when speaking of *Ptilodictya*, and in speaking of *Sulcoretepora* (B.A. Rep. 1880) I fell into an error with regard to the axial region. This was pointed out to me by Mr. John Young, but I have had no opportunity of correcting it until now, and reference has been made to the error when writing of *Sulcoretepora*.

[1] See figures in either Busk's *Cyclostomata* or Hincks's *Brit. Mar. Polyzoa.*

In spite, however, of all that has been written about this 'laminar axis' in Polyzoa, I have always had my doubts about its existence, and I did not care to venture into the domain of mere disputation until I could give some tangible proof that my views were correct. I ventured to touch upon the question in my paper on the 'Wenlock Polyzoa.' In that paper I wrote (*op. cit.* p. 66), when speaking of *Ptilodictya Lonsdalei*, Vine: 'I refuse to say cells "separated by a thin laminar axis," because this is not so in this species at least. The "axis," if such it may be called, is formed by the bases of the cells, both in transverse and in longitudinal sections.' After giving the views of Mr. John Young of Glasgow, and also recording my own observations on the specimens in the School of Mines, and the observations of Prof. Nicholson, I pass on to say: 'This being a matter of extreme importance, I shall return to its discussion at some future time when other investigations which I am making are completed.'[1] I cannot say whether or not Mr. Ulrich has seen the above remarks. If he has not, I must then take his testimony as independent, but in October 1882,[2] when criticising remarks made by Prof. Nicholson ('Monticulipora,' p. 196, 1881), Mr. Ulrich says: 'If I understand him (Nicholson) correctly, he believes that the axis is constituted by a *definite structure* from which the two layers of cells may be stripped. This impression is manifestly erroneous, nor do I know of a single double-leaved Bryozoon in which such a structure may be demonstrated. In *Ptilodictya* the facts are simply that we have two layers of cells which are grown together back to back by the adhesion of the epithecal laminæ of each layer.' So far the observations of Mr. Ulrich agree with my own, but because of this I am not prepared to accept the further view that *Monotrypa pavonia*, D'Orb. ('*Monticulipora*,' p. 195), is a *Ptilodictya* ('American Pal. Bryozoa,' pp. 163–4).[3] It is very evident that our Silurian rocks are remarkably poor in species of *Ptilodictya*, and it gives me great pleasure to acknowledge the varied labours of Mr. Ulrich and Mr. J. M. Nickles in working out what they prefer to call 'Bryozoa.'

VII. The endosarcal passages. If we are to accept the views of the leading writers on the development of Polyzoa, then some little attention should be given to what I venture to call 'endosarcal passages' in the zoarium of fossil species. Whenever we examine with a high power the supposed contiguity of the cells, we generally find between the 'epitheca' of cell and cell very delicate hollow spaces. In longitudinal sections of *Ptilodictya* the hollow spaces intervene all along the so-called 'laminar axis,' and the alternate cells at their bases appear to open into this tube-like hollow. In *Fenestella*, and also in various species of '*Pinnatopora*,' I have detected similar hollows. In the *Graptolites* the 'cellules' of certain species open into what is called the 'canal,' a space intervening between the 'solid axis' and the cellules, through which the 'organic pulp passed into the cells.' I have not the least doubt but that through these passages in the ancient *zoaria* of the Polyzoa the endosarc passed from cell to cell. It is not in every section that I have made that I have been able to detect the passages; still they are found in some, and I have

[1] Read Dec. 1881. Pub. *Quar. Jour. Geo. Soc.* Feb. 1882.
[2] *American Palæozoic Bryozoa*, p. 164.
[3] I have a specimen of *Monotrypa pavonia*, D'Orb., from the Cincinnati beds, before me while I write.

no doubt but that other workers will find them if the sections are carefully prepared. At the bases of some cells I have also detected circular openings, and as this would be the probable position of the funiculus of the polypide, this seems to me to be additional proof of the view I take. I have never been able to detect in any fossil specimens ordinary 'rosettenplaten' (communication pores, Hincks) other than the above, and I am unable to furnish better details than the one already given; neither have I been able to detect in any of my numerous sections 'connecting foramina' similar to, or in any way analogous with, the structure of the cell wall in *Ptilodictya maculata*, Ulrich, figured in the 'Am. Palæozoic Bryozoa,' pl. VI. fig. 17.

VIII. The tabulæ. I have already said that I have not been able to detect 'tabulæ' in any well-accredited species of Fossil Polyzoa. In *Ptilodictya* figured by me now, I have allowed a structure to appear which may be mistaken for tabulæ, but I think this would be an erroneous interpretation. I refer to the subject because Professor Nicholson describes tabulæ in *Heterodictya*, and Mr. Ulrich refers to 'diaphragms' in some of the 'robust cells' of species of the genus. I have no desire to enter into controversy with other authors, but I hope that Professor Nicholson and also Mr. Ulrich will pardon me for making the following remarks on their labours. In 'The Genus *Monticulipora*,' p. 89, Professor Nicholson furnishes particulars of *Heterodictya gigantea*, Nich., and he gives figures of minute structures of the type. In the sections tabulæ are figured, and the walls are of a very peculiar character. This species, and in fact many of the American *Ptilodictya*, differ from the type already described.

Mr. Ulrich (*op. cit.* p. 162) accepts the genus *Ptilodictya*, Lonsdale, in which he includes *Heterodictya*, Nicholson ('Geo. Mag.' 1875), but the characters which he gives as a diagnosis are not those of Lonsdale. I am obliged therefore to fall back very reluctantly upon my own labours, which have now been carried on for a series of years; and accepting *Ptilodictya Lonsdalei* as the type, I found the following family for the inclusion of a certain number of Palæozoic Polyzoa.

Family ARCANOPORIDÆ, Mihi.

Zoarium multiform. *Zoœcia* tubular, or semitubular, orifice of cell obscured by vestibule; true orifice of cell unknown.

Genus *Ptilodictya*, Lonsd.	Type *P. Lonsdalei*, Vine.
„ *Arcanopora*, Vine.	„ *Flustra? parallela*, Phill.
„ *Glauconome*, Goldf.	„ *G. disticha*, Goldf.

PTILODICTYA, Lonsdale.

Diagnosis of the genus already given.

At present a revision of *Ptilodictya* seems to be impossible, but I may just indicate that the founding of two family names by Mr. Ulrich, *Ptilodictyonidæ* and *Stictoporidæ*, appears to be warranted by the peculiar character of the cell orifice, as well as by the cell arrangement. The only American species that comes nearest to *P. Lonsdalei*, Vine, is some specimens of *Rhinodictya granulosa*, James, supplied to me by Mr. J. M. Nickles. These, however, differ from the species *R. granulosa*, James,

embedded in Limestone, which Mr. Nickles has also sent me. This appears to be the species which Mr. Ulrich renames *R. Nicholsoni*, Ulrich. Under present circumstances I can only catalogue the following British species:—

Wenlock Shales	*Ptilodictya Lonsdalei*, Vine.
,, Limestone	,, *lanceolata*, Lonsdale.

Mr. J. M. Nickles has also pointed out to me that the species which I have called *P. interporosa*, Vine (Wenlock Polyzoa, 'Quart. J. G. Soc.' p. 67), is not a *Ptilodictya* at all, but that it closely resembles *Stictoporella flexuosa*, James. It certainly very closely resembles the delicate species of James, but it differs considerably from Mr. Ulrich's *S. interstructa*. I shall therefore adopt the generic, and retain my own specific name.

Wenlock Shales.	*Stictoporella interporosa*, Vine (=Ptilodictya interporosa).
,, ,,	,, sp.

There still remains *P. scalpellum* (Eschara), Lonsdale, which for the present must remain in abeyance. This also is not a *Ptilodictya*.

Arcanopora, Vine.

= *Sulcoretopora*, D'Orb. (pars) of authors.
Type *Flustra ? parallela*, Phill. 'Geo. of Yorkshire.'

Zoarium ?——. *Zoœcia* arranged in parallel lines on opposite sides of the *zoarium*.

Sulcoretepora was founded by D'Orbigny in 1847, and since then a variety of species of very different characters have been included in the genus. Professor Morris, in his 'Catalogue of Brit. Fossils,' places the genus in his family *Reteporidæ*, a *Cheilostomatous* type, and it is uncertain how authors regard the character of the species placed in it. In the 'Catalogue,' Professor Morris includes the *Flustra parallela* of Phill., and the *Vincularia raricosta*, M'Coy. As the definition given by D'Orbigny is evidently inapplicable to these species—'Cells in series in furrows on one side of simple depressed branches'—the name ought to be dropped. At present I can only direct attention to the species already named, to which the Messrs. Young have added another—*Sulcoretepora Robertsoni*, Y. and Y. I have not yet completed my investigations, but I have sufficient evidence to induce me to include the first two species in the present group.

Glauconome, Goldfuss, restricted.

'Stem stony, thin, elongated oval, branched, cells disposed longitudinally, and alternately in rows over one half the surface, the other half striated longitudinally. Nature of the covering and opening of the cells unknown. Silurian System, pl. XV. fig. 12, and *c* (p. 675).

The above is Lonsdale's description of this restricted genus, and as the type of Goldfuss and Lonsdale is the same species—*G. disticha*, Goldf.—it seems to me desirable that both the genus and species should be limited to the type, unless the earlier Bala species can be included in the same genus. It is very evident that the structural characters of the Carboniferous species that have heretofore been included in the genus are

different, for Lonsdale says that *G. disticha* has 'four rows of long quadrangular cells on one side' of the zoarium.

Wenlock Shales.	*Glauconome disticha.*[1]	Lonsdale's sp.
„ Limestone.	„	„

Family Rhabdomesontidæ.

Zoarium rod-like, branching. *Zoœcia* opening on all sides of the branch, tubular, attached by their proximal extremities to a central rod. Orifice of cells obscured by vestibule; wall of vestibule externally ornamented by spines or not.

Rhabdomeson, Young & Young.

(See 'Bibliography' for references.)

Although the Messrs. Young have written two papers on *Rhabdomeson* species, they have not, so far as I am aware, given other than brief descriptions of the genus. In their first paper ('Ann. Mag. Nat. Hist.' May, 1874), after reviewing the history of *Ceriopora*, they say: 'The essential character of the fossil we are about to describe (*Millepora gracilis*, Phill.) separates it from all known Carboniferous forms; we would suggest *Rhabdomeson* as the generic name, the axis being central, not lateral as in Allman's *Rhabdopleura*. (See Hinck's 'Brit. Mar. Polyzoa,' p. 577.)

In describing one of these figures the authors speak of the 'vestibules' of the cells being filled with matrix. I have satisfied myself by sections that these vestibules really exist in species, and I give below the two at present known to exist.

Devonian and Carb.,	*Rhabdomeson gracile*, Phill.	=*Millepora*, Phill.
	„	=*Ceriopora*, Morris.
Carboniferous,	„ *rhombiferum*	=*Ceriopora*, Phill.

Part III.

Pseudo-Polyzoan Forms.

=Bryozoans of American and other Authors (pars).

I think it would be unwise to allow this Report to pass out of my hands without directing the attention of the palæontologist to what I have ventured to call Pseudo-Polyzoan Forms, some of which are very common in the Wenlock Series of Rocks, but the types are described from the Cincinnati Rocks of America.

Family Arthronemidæ, Ulrich.

'*Zoarium* dendroid, composed of numerous small sub-cylindrical segments, carrying cells on one or both sides.'—'Amer. Palæoz. Bryozoa' (*op. cit.*), p. 151.

[1] The so-called *Glauconome disticha*, of the Bala Beds, which has been described and figured by Mr. Robert Etheridge, jun., as a variety of Toula's *Ramipora*, is being investigated by Mr. G. W. Shrubsole, F.G.S.

In this family, Mr. Ulrich places two genera, one of which he calls *Arthronema*, Ulrich, which from the figures and description appears to be a true Polyzoon. The other genus is *Arthroclema*, Billings. In this genus the segments are cylindrical, with cell apertures opening on all sides. There are species in the Wenlock Shales closely related to, if not identical with, the American forms, but I have no evidence of the further character given by Mr. Ulrich: '*Zoarium* composed of numerous segments . . . . pointed more or less obtusely at both ends.'

There is another species of a genus—*Auxanopora*, Nickles MS.—closely related to Wenlock Shale species; but as Mr. J. M. Nickles has not yet published details of the type, I am not at liberty to refer to it more pointedly at present. The type of the genus is *Chætetes minuta*, James, No. 266 of Mr. Ulrich's Catalogue. ('Cat. of Foss. occurring in the Cincinnati Group of Indiana and Kentucky,' E. O. Ulrich, 1880.)

There are still several other fossils that would form a group here by themselves, for the whole of the *Ceriopora* of the Silurian Rocks may be conveniently reworked.

Family Ceramoporidæ, Ulrich.

This is another of the families of Mr. Ulrich in which some of our Silurian and Carboniferous forms may ultimately be placed. They are not, however, in the strict sense of the term, Polyzoa.

Genus *Ceramopora*, Hall.
,, *Ceramoporella*, Ulrich.
,, *Cheiloporella* ,,
Genus *Crepipora*, Ulrich.
,, *Eridopora* ,,

Part IV.

Bibliography.

Bibliography of Palæozoic and Mesozoic Polyzoa published in Great Britain, in various periodicals, since the publication of Professor Morris's 'Catalogue of British Fossils,' 1854.

E. W. Claypole, B.A., F.G.S.

1883. On *Helicopora latispiralis*. A new Spiral Fenestellid from the Upp. Sil. Beds of Ohio, 'Quart. Jour. Geo. Soc.' May 1883.

Prof. P. M. Duncan and Mr. H. M. Jenkins.

1869. On *Palæocoryne*, from the Carb. Formation, 'Phil. Trans.' clix. p. 693.
1873. On the Genus *Palæocoryne* and its Affinities, 'Quart. Jour. Geo. Soc.' xxix. p. 412.
1874. Remarks on Messrs. Young's paper on *Palæocoryne*, Quart. Jour. Geo. Soc.' xxx. p. 684.

Robert Etheridge, F.R.S.

1881. Anniversary Address. Analysis and Distribution of Brit. Palæozoic Fossils (Polyzoa), 'Quart. Jour. Geo. Soc.' Feb. 1881.
1882. Second Presidential Address. Analysis and Distribution of Brit. Jurassic Fossils (Polyzoa), 'Quart. Jour. Geo. Soc.' May 1882.

Robert Etheridge, jun., F.G.S.

1873. Explanation of Sheet 23 Geo. Survey, Scotland. In the descriptive Palæontology of this sheet Mr. Robert Etheridge, jun., gives descriptions of New Carboniferous Polyzoa, *Carinella cellulifera*, *Fenestella bicellulata*, *F. tuberculo-carinata*, *Polypora* (*Thamniscus*) sp., *Synocladia biserialis*,

Swallow, var. *carbonaria*, Eth. jun., and *Vincularia?* (*Rhabdomeson?* sp.)

1873. On *Synocladia carbonaria* (referred to above), 'Ann. Mag. Nat. History,' 1873.

,, Description of *Carinella*, 'Geo. Mag.' Dec. 1, x. p. 443.

1875. Observations on some Carb. Polyzoa, 'Proc. Geo. Assoc.' vol. iv. No. 2, pp. 116–122 (plate): On *Synocladia*, *Polypora*, and *Thamniscus; Synocladia biserialis*, var. *carbonaria*.

,, Note on New Provisional Genus of Carb. Polyzoa, 'Ann. Mag. Nat. Hist.' ser. iv. vol. xv. pp. 43–45 (plate): *Hyphasmapora*, new genus; *H. Buskii*, new species.

1876. Carboniferous (and Post-Tertiary) Polyzoa, 'Geo. Mag.' Dec. 2, vol. iii. pp. 522, 523. Proposes the name *Goniocladia* (= *Carinella*, Eth. jun.)

1877. Notes on Carb. Polyzoa, 'Ann. Mag. Nat. Hist.' ser. 4, vol. xx. pp. 30–37 (plate). Describes *Fenestella scotica* (new var. = *F. tuberculo-carinata*, Eth. jun. G.R.V.), and *Glauconome elegantula*, Eth. jun. (= *G. laxa*, Y. & Y. G.R.V.) Criticises *Glauconome* and *Thamniscus Rankini*, Y. & Y. Observations upon the genus *Rhombopora*.

1878. Arctic Palæozoic Polyzoa, 'Quart. Jour. Geo. Soc.' 1878, June 1.

1879. Remarks on the Genus *Ramipora*, Toula, and description of *R. Hochstetteri*, var. *carinata*, Eth. jun. 'Geo. Mag.' 1879, p. 241.

F. D. Longe, F.G.S.

1881. On the relation of the Escharoid Forms of Oolitic Polyzoa, 'Geo. Mag.' Jan. 1881.

In the following papers by Professor Nicholson the author treats of American Palæozoic Polyzoa chiefly; but as the papers have been published in this country as well as in America, their study should not be neglected. Those on the Devonians of America are especially valuable to the palæontologist.

Professor H. Alleyne Nicholson, F.G.S. &c.

1874. New Devonian Fossils of Canada West, 'Geo. Mag.' Dec. 2, vol. i.

The description runs through several numbers, and the Polyzoa belong to the genera *Tæniopora*, *Ptilodictya*, *Clathropora*, *Botryllopora*, *Ceriopora?*, *Polypora*, *Phyllopora* (*Retepora* of paper), and *Fenestella*.

1875. Descriptions of New Species and a New Genus of Polyzoa from the Palæozoic Rocks of North America, 'Geo. Mag.' Jan. 1875. Describes *Heterodictya*, *Ptilodictya*, *Fenestella*, *Ceramopora*, *Phyllopora Trentonens* (*Retepora* of paper).

1874. Descriptions of two New Genera and Species of Polyzoa from the Devonian Rocks of Western Ontario, 'Ann. Mag. Nat. Hist.' Feb. 1874. Describes *Cryptopora* and *Carinopora*.

1875. Description of Species of *Hippothoa*? and *Alecto* from the Lower Sil. Rocks of Ohio, with description of *Aulopora arachnoidea*, Hall, 'Ann. Mag. Nat. Hist.' Feb. 1875. Describes *Alecto* (*Hippothoa* of paper) *inflata*, *auloporoides*, *frondosa*, and *confusa*.

,, Description of New Species of Polyzoa from the Lower and Upper Sil. Rocks of North America, 'Ann. Mag. Nat. Hist.' March 1875. Describes *Ptilodictya*, *Fenestella*, and *Ceramopora*.

1877. On *Ascodictyon*, a New Provisional and Anomalous Genus of Palæozoic Fossils (Nicholson and Etheridge, jun.), 'Ann. Mag. Nat. Hist.' June 1877.

G. W. Shrubsole, F.G.S.

1879. A Review of British Carboniferous Fenestellidæ, 'Quart. Jour. Geo. Soc.' May 1879.

1880. Review and Description of British Upper Silurian Fenestellidæ, *op. cit.* May 1880. Describes three new species of *Fenestella*—*F. reteporata*, *F. lineata*, and *F. intermedia*, and accepts *F. rigidula*.

1881. Further Notes on Carboniferous FENESTELLIDÆ, *op. cit.* May 1881. Redefines the genus *Fenestella*, Lonsdale, and describes a new species, *F. Halkinensis*.

1882. On the Occurrence of a New Species of *Phyllopora* (*P. multipora*) in the Permian Limestone, *op. cit.* Aug. 1882.

„ THAMNISCUS: Permian, Carboniferous, and Silurian, *op. cit.* Aug. 1882. Describes and figures *P. crassus* = *Hornera crassa*, Lonsdale.

Professor TATE, F.G.S.

1875. Description of *Spiropora*, &c., 'Geo. Mag.' 1875.

G. R. VINE.

1877. Chapters on Carboniferous Polyzoa, 'Science Gossip,' 1877, pp. 108–110, 152–156, 220–222, 271–274.

1878. The Genus *Fenestella*: its History, Development, and Range in Space and Time, 'Science Gossip,' 1878, pp. 247–250, 274–276.

1879. Physiological Characters of *Fenestella*, *op. cit.* pp. 50–54.

„ On *Palæocoryne*, Duncan and Jenkins, &c., *op. cit.* pp. 225–229, 247–249.

„ Polyzoa of the Carb. Epoch, Paper read before the Lit. and Philosophical Soc. Shef., Report of Soc. pub. 1880.

1880. A Review of the Family DIASTOPORIDÆ, Busk, 1st paper, 'Quart. Journ. Geo. Soc.' Aug. 1880.

„ 1st Report on Carb. Polyzoa, 'Brit. Association Reports,' Swansea, 1880.

1881. Further Notes on the Family DIASTOPORIDÆ, Busk, 'Quart. Jour. Geo. Soc.' Aug. 1881. Describes four new species of Oolitic *Diastopora*.

„ Silurian Uniserial *Stomatopora* and *Ascodictya*, 'Quart. Journ. Geo. Soc.' Nov. 1881. Describes as new *S. dissimilis* and *Ascodictya* sp.

„ 2nd Report. Silurian Polyzoa, 'Brit. Association Reports,' York, 1882.

1882. Notes on the Polyzoa of the Wenlock Shales, &c., 'Quart. Jour. Geo. Soc.' Feb. 1882. Describes several new species of Polyzoa.

„ Notes on the Carb. Polyzoa of North Yorkshire, 'Trans. Geolog. and Polytechnic Soc. of the West Riding of Yorkshire,' March, 1882.

„ The DIASTOPORIDÆ, or the Natural History of a Family Type, 'Science Gossip,' April, July, and Nov.

„ 3rd Report. Jurassic Polyzoa, Brit. Area only, 'Brit. Association Reports,' pub. Dec. 1882.

1883. Notes on the Polyzoa of Derbyshire and Yorkshire, 'Trans. of the Geological and Polytech. Soc. of the West Riding of Yorkshire.'

„ Fourth Brit. Assoc. Report on Fossil Polyzoa. Cretaceous Polyzoa and New Classification.

A. W. WATERS, F.G.S.

1878. Remarks on some *Fenestellidæ*, 'Transactions of Manchester Geo. Soc.' 1878.

Professor JOHN YOUNG and Mr. JOHN YOUNG (Hunterian Mus. Glasgow).

1874. New Carb. Polyzoa, 'Quart. Jour. Geo. Soc.' vol. xxx. pp. 681–683 (2 plates).

„ *Actinostoma* (n. gen.), *A. fenestratum* n. sp., *Glauconome stellipora*.

„ On *Palæocoryne* and other Polyzoal Appendages, *ibid.* pp. 684–687 (plates).

„ On a New Genus of Carb. Polyzoa, 'Ann. Mag. Nat. Hist.' ser. 4, vol. xiii. pp. 335–339 (plate). *Rhabdomeson*, Y. & Y. *R. gracile* (= *Millepora gracilis*, Phill.).

„ Note on the Occurrence of *Polypora tuberculata*, Prout, in Scotland, 'Geo. Mag.' Dec. 2, vol. i. pp. 258–9.

1875. On New Carb. Polyzoa, 'Ann. Mag. Nat. Hist.' ser. iv. vol. xv. pp. 333–336 (plates). *Rhabdomeson* = *Ceriopora rhombifera*, Phill. Also remarks on *C. similis*, Phill., and *C. interporosa*, Phill., and describes *Thamniscus? Rankini*, Y. & Y.

1876. New Species of *Glauconome* from Carb. Limest. Strata of West of Scot., 'Proc. Nat. Hist. Soc. Glasgow,' vol. ii. pt. ii. pp. 325–335 (plates). *Glauconome marginalis*, *G. elegans*, *G. aspera*, *G. flexicarinata*, *G. retroflexa*, and *G. laxa*. Subgenera proposed *Diplopora* and *Acanthopora*.

1877. Notes on a New Method of fixing Fronds of Carb. Polyzoa on a layer of Asphalt, &c., 'Proc. Nat. Hist. Soc. Glasgow,' vol. iii. pl. II. pp. 207–210, and 'Science Gossip,' vol. xiii. No. 151, pp. 158–159 (Mr. John Young).

„ A New Species of *Sulcoretepora* (Carboniferous), 'Proc. Nat. Hist. Soc. Glasgow,' vol. iii. pt. ii. pp. 166–168 (plate). Describes *S. Robertsonii*, Y. & Y.

1878. On two New Species of Carb. Polyzoa, 'Proc. Nat. Hist. Soc. Glasgow,' vol. iv. pp. 354–356 (plate). *Glauconome robusta*, Y. & Y. *Synocladia ? scotica*, Y. & Y.

1879. Notes on the Perfect Condition of the Cell-pores and other Points of Structure in certain Species of Carb. Polyzoa (Mr. J. Young), 'Trans. Geo. Soc. Glasgow,' Oct. 1879.

1880. Notes on Carb. Species of *Glauconome* (Mr. John Young, F.G.S.), 'Proceed. Nat. Hist. Soc. Glasgow.'

1881. Remarks on the Genus *Synocladia*, and other allied forms, with description of new Species, *Synocladia ? fenestrelliformis*, 'Proceed. Nat. Hist. Soc. Glasgow,' Jan. 1881.

1882. On the Identity of *Ceramopora* (*Berenicea*) *Megastoma*, M'Coy, with *Fistulipora minor*, M'Coy, 'Ann. Mag. Nat. Hist.' Dec. 1882.[1]

This report completes my labours for the present on British Fossil Polyzoa. The reports are not all that I could have wished, and in the earliest—the Carboniferous Report—there are many defects in the style, composition, and descriptive text that I, at present, lament, but the whole were unavoidable at the time. In the compilation of the various reports I have received from specialists much kindly help and attentive consideration—for all of which I return them my sincere thanks. To Professor P. Martin Duncan, F.R.S., and also to Dr. H. C. Sorby, F.R.S., names associated with mine as the Committee for the compilation of these reports, my thanks are also due for the extremely kindly manner in which they have given advice, and help by way of suggestion, whenever solicited for the same. The General Committee of the British Association must also be remembered by me on account of their kindly consideration of my humble efforts, and for their pecuniary help.

Fourth Report of the Committee, consisting of Professor W. C. Williamson *and* Mr. W. H. Baily, *appointed for the purpose of Investigating the Tertiary Flora of the North of Ireland. Drawn up by* William Hellier Baily, *F.L.S., F.G.S., M.R.I.A.* (*Secretary*).

[Plate I.]

The Secretary regrets the unavoidable delay which has occurred in supplying this report, which should have been presented at the last year's meeting of the Association. He has lately had an opportunity of pursuing his researches on the Tertiary Flora of the North of Ireland, and has been enabled to obtain some additional information as to the relation of these deposits with that of other portions of the British Islands.

Most important amongst these fossil plants is a second example of a fossil fern, which he believes to be identical with *Lastrea Stiriaca* (Unger).

[1] I shall be sorry if such is the case, but I may have overlooked some papers on Palæozoic and Mesozoic Polyzoa. If so, I hope authors will communicate with me.

This specimen, which is figured on the plate accompanying this report, is in the collection of the Rev. Canon Grainger, D.D., Rector of Broughshane, who has aided considerably in these investigations. It is a portion of a pinnule, with about eight alternating leaflets on each side, on which the midrib and nerves are strongly marked, and not forked, except at their apex.

With reference to this fern, Dr. Oswald Heer, in his description of the fossil flora of Bovey Tracey, Devonshire,[1] in alluding to the 'Miocene' formation of Bovey, says: 'Of fifty species of plants found in the lignite beds of Bovey twenty-one occur also on the Continent in the Miocene formation. The lignite of Bovey Tracey is, therefore, undoubtedly Miocene; and it is worthy of special remark that the species of *Cinnamonium* which are so characteristic of the Miocene, and so generally distributed through it, make their appearance in Bovey precisely as in the lignites and molasse of the rest of Europe; equally characteristic is the *Lastrea Stiriaca*, the fern of most universal distribution over Miocene Europe.'

The importance of the discovery of this fern in the ironstone deposits of the North of Ireland cannot therefore be overrated after this expression of opinion as to its value in determining the age of the strata in which it is found, on the authority of so eminent a fossil botanist as that of Professor Heer.

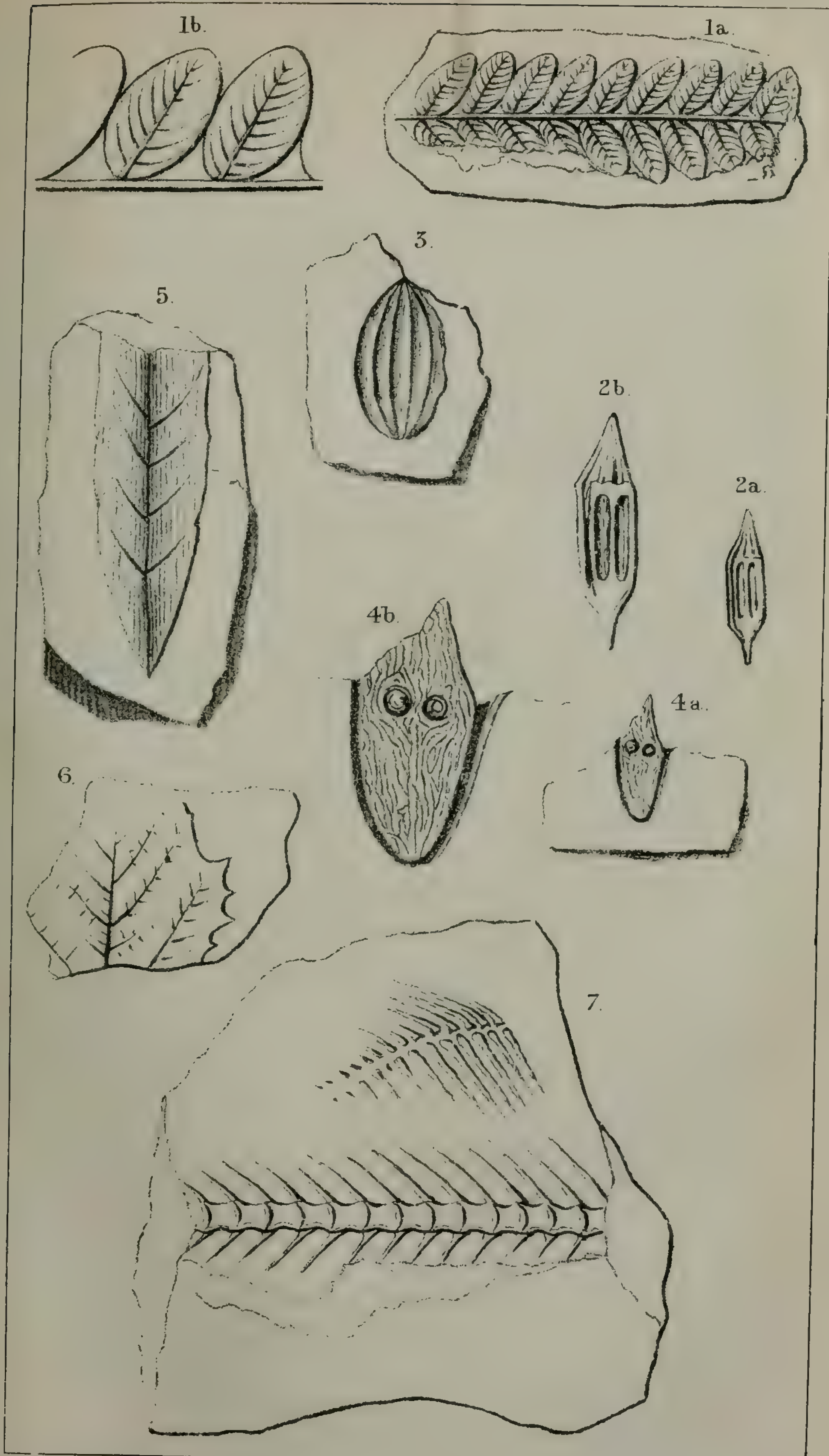
Mr. J. Starkie Gardner, F.G.S., who has been for some time studying the Coniferæ, and lately visited this country for the purpose of examining these collections, has very kindly furnished me with a few notes on them. He thinks (as far as his observations lead him at present) there is but one or two species of pine; 'cones of *Thuya* (Cupressinæ) abound; cones of *Sequoia* are rarer; *Coniferæ* outnumber leafy trees by at least twenty and possibly one hundred fragments to one; *Magnolia* fruits are as about one to five against pine cones.' He also states that 'he has seen (in these collections) several specimens of *Nelumbium* (a water-lily);' all these names, as he observes, must at present be taken as provisional, except *Pinus*. 'There are two other conifers, both specimens unique, and both Greenland forms.'

The Rev. Dr. Grainger was also fortunate enough to obtain a portion of a fossil fish, which was found in a drift boulder of red or ochrey marl (resembling that of some of the deposits at Ballypalady), at Culleybackey, near Ballymena. It consisted of twelve or more vertebræ, with their processes, above which are bones of the dorsal fin, and may have belonged to a fresh-water fish of the Percidæ, such as the genus *Lates*. This fossil is of considerable interest, as no remains of Vertebrata have, so far as we are aware, hitherto been found in British strata of this age.

Explanation of Plate I.

Fig. 1. *a*. Lastrea Stiriaca (Unger) pinnule, nat. size.
„ 1. *b*. „ „ „ portion enlarged 2 diameters.
„ 2. *a*, *b*. Nyssa ornithobroma (Heer) in ironstone, shore of Lough Neagh. *a*. Nat. size. *b*. Enlarged $1\frac{1}{2}$ diameters.
„ 3. ? Carpolithus sulcatulus (Heer) (same loc.).
„ 4. *a*, *b*. „ follicularis (Heer). *a*. Nat. size. *b*. Enlarged (same loc.).
„ 5. ? Quercus Lyelli (Heer). Drift clay, shore of Lough Neagh.
„ 6. ? Salix varians (Heer). „ „ .
„ 7. Fish. ? Lates or Perca.

[1] *Philosophical Transactions*, 1862, p. 1039 et seq.



W. H. Baily del. Spottiswoode & Co. Lith. London.

Illustrating the Report on the Tertiary Flora, &c., of the Basalt of the North of Ireland.

Report of the Committee, consisting of Mr. R. ETHERIDGE, Mr. THOMAS GRAY, *and* Professor JOHN MILNE (*Secretary*), *appointed for the purpose of investigating the Earthquake Phenomena of Japan.*

OWING to my absence from Japan, on a visit to Europe, during six months of the past year, and a complication of circumstances involving the removal of my seismological laboratory, over which I had no control, the work accomplished in actual observation has been small.

While passing through America, and subsequently when in Italy, I saw and learnt much respecting observations which may with advantage be amplified and repeated in Japan.

When in England, I entered, in conjunction with Mr. Thomas Gray, into arrangements with Mr. James White, of Glasgow, for the construction of a seismometer. This instrument, which gives a complete diagram of all the sensible vibrations of an earthquake in conjunction with the time of occurrence of these vibrations, was exhibited before the Geological Society of London, and is described in their 'Proceedings.' [1]

The instrument is now in Japan. By request it has been exhibited to His Imperial Majesty, the Mikado of that country, and very shortly it will be erected, in all probability, at the Meteorological Observatory in Tokio.

One class of phenomena which I have been engaged in observing since my return to Japan, is earth-tremors. These microseismic movements of the soil I observed some years ago, with an instrument similar in principle to the apparatus used by Messrs. George and Horace Darwin, at the Cavendish Laboratory, when engaged in the attempt to measure the lunar disturbance of gravity.[2]

The apparatus that I have employed during the last five months is similar to the Tromometer of Bertelli and Rossi. It consists of a weight suspended by a very fine wire, the whole being enclosed in a tube, for protection against currents of air. Projecting downwards from the weight there is a stile, which is observed with a microscope containing a micrometer scale. The whole, which is supported on an iron stand, rests on the head of a stone column. The column is about ten years old. It is inside a brick building, from the walls and floors of which it is completely detached.

Hitherto I have not had the time which is necessary to analyse the mass of observations which have already been accumulated, but the following points are very clear.

1. It is but seldom, if ever, that the pendulum is completely at rest.

2. A vertical motion is occasionally observed in the pendulum, the stile of which oscillates up and down with a rapid tremulous movement.

3. At times the horizontal swing of the pendulum is very irregular, the oscillations being performed in short jerky swings which vary in amplitude.

4. With sudden changes in the barometer, the motions of the pendulum are relatively very great.

5. The pendulum does not always oscillate or hang over the same point. There is a change in the vertical.

These results are similar to results obtained by Bertelli, Rossi, and other observers in Italy.

[1] *Quart. Journ. Geol. Soc.* vol. xxxix. 8.

[2] See *Report*, 1881, p. 93; 1882, p. 95.

The cause of these movements is unknown. Rossi makes the suggestion that they may be due to a variation in volcanic activity beneath the surface of the ground, which increases with a barometrical depression. They may, however, be attributed to a complexity of causes acting on the surface of our earth. At the time of a high wind the movements of houses and trees may set the surface of a considerable area into a state of tremor. When they are observed without a wind they may occasionally be due to an irregularity in the increase or decrease in atmospheric pressure. In a typhoon I have observed the needle of an ordinary aneroid to move backward and forward through a range of from $\frac{1}{100}$ to $\frac{5}{100}$ of an inch. This motion was irregular, having a period of from one to ten seconds. Small but rapidly succeeding variations in atmospheric pressure, even very much smaller than those just quoted, indicate that the surface of the ground is being subjected to and relieved from stresses, in every probability, competent to produce the oscillations observed in the pendulum.

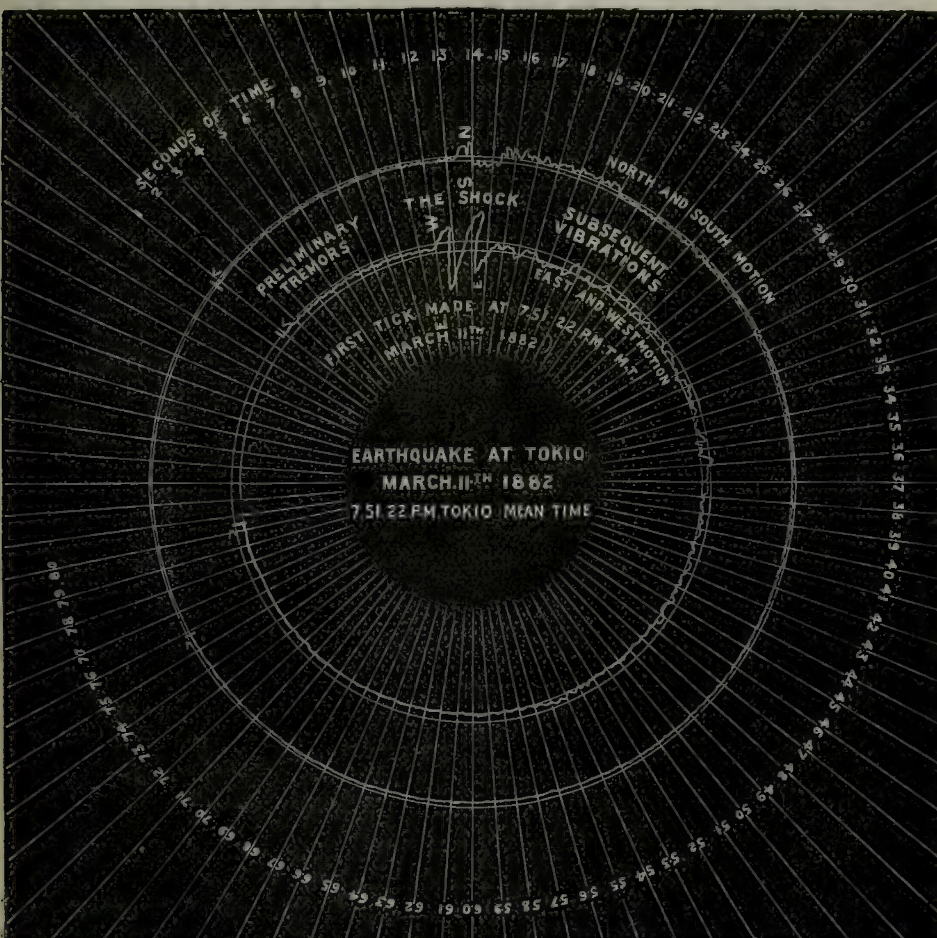
A second set of observations has been recording the motions of the bubbles of two delicate levels placed beneath glass covers on the same column with the tromometer. One of these is placed N. and S. and the other E. and W. The variation in temperature in the room seldom exceeds 1° or 2° F. per day. These levels have shown continual movements. At present the N. and S. level has a diurnal backward and forward motion of about three divisions. One division equals about 2″ of arc. As an example of the larger movements which have been recorded, I may state that the bubble of the N. and S. level moved, from March 25 to May 4, through twenty-nine divisions. The direction of the deflection of the tromometer pendulum has a general correspondence with these larger movements. A curious phenomenon which has been observed in the levels is that accompanying a barometrical depression—there is a slight surging in the bubbles. The surge, which has an amplitude of from ·25 to ·5 of a division is irregular, having a period of from 1 to 5 or 6 seconds.

This motion, inasmuch as it is different from the effects produced by alterations in temperature, and as it accords with the microseismic movements of the tromometer, I am inclined to attribute to a true earth-pulsation.

Another phenomenon indicative of the existence of earth-pulsations —by which I mean motions which may have an amplitude equal to that of an earthquake, but which are not perceived on account of the slowness of their period—is the slow surge-like motion in a level, which continues for fully three or four minutes after all sensible motion of an earthquake has disappeared. This surging, as it dies out, closely accords with the surge observed at the time of a barometrical depression.

This last observation is supplementary to observations made on an earthquake with a seismograph. The records from a seismograph show that a moderately strong disturbance sometimes commences as a series of tremors with a frequency of from 4 to 6 per second. These movements are so small in amplitude that, unless an observer is favourably situated, they are passed by unnoticed. While they continue, however, I have heard pheasants scream, and it has been noticed that frogs cease their croaking. Immediately after the tremors we get the shock of the earthquake, some of the vibrations of which have occasionally been performed so rapidly that I have failed to measure their duration. It is not unlikely that this portion of an earthquake may take place so suddenly that rocky strata in the immediate vicinity of the origin have not time for elastic

yielding. The effect is that of a sudden push. The area thus affected my colleague, Professor T. Alexander, has called the *core* of the earthquake. The existence of an earthquake-core is one means of explaining the enormously high velocities of propagation which I and other observers have from time to time recorded. After the *push* or *shock* come the resulting irregular tremors. These continually slow down in their period until, when they reach a period of two or three seconds, the seismograph ceases to act. The slow irregular surging of a level appears to be a continuation of the record of a seismograph.



In these respects the vibratory motions of an earthquake are analogous to a spectrum of light—there being two extremities which with ordinary instruments are usually unobserved—at one end because the vibrations are too quick, and at the other end because they are too slow. The accompanying diagram of the earthquake of March 11, 1882, shows the portion of an earthquake registered by an ordinary seismograph.

A set of experiments which I am now engaged upon in Japan has for its object the determination of some true measure of the intensity of an artificial disturbance produced by the explosion of a charge of dynamite as it radiates from its origin. Rather than estimate the intensity of an impulse at a point, by vague terms or by an arbitrary scale of degrees, I have attempted to measure the intensity of a shock by the stresses it is

capable of producing in bodies on the earth's surface. One estimate of these stresses is the acceleration a body receives.

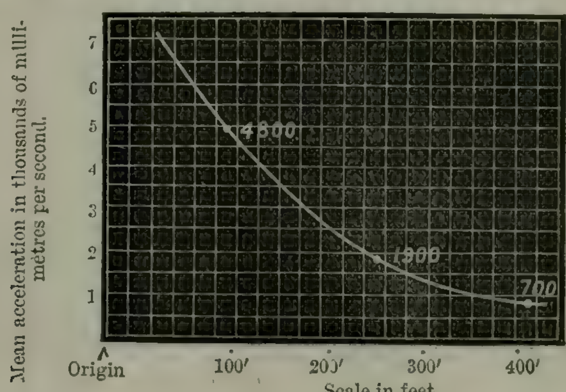
Intensity thus defined may be written $\frac{V^2}{a}$, where V is the maximum velocity of a vibrating particle, and a is its amplitude, or half a semi-oscillation. This quantity, $\frac{V^2}{a}$, is the maximum acceleration of an earth-particle, assuming the motion to be simple harmonic.

I have calculated $\frac{V^2}{a}$ for the prominent vibrations of a number of disturbances, each disturbance being recorded at several stations.

The results of these calculations show that as a disturbance radiates the intensity dies out, rapidly at first, but eventually very slowly. The results give a curve which is a rough approximation to an equilateral hyperbola.

From these observations it would appear that by obtaining the curve of intensity for any given disturbance we may, by comparing with the curves obtained by the explosion of known charges of dynamite, approximately obtain some absolute measures of earthquake energy.

The accompanying diagram gives the mean of the results obtained in a series of experiments in which the surface of the ground was put into vibration by the explosion of charges of dynamite put into bore-holes about ten feet deep. The ordinates give intensity, and the abscissæ distance from the origin in feet.



Curve of Earthquake Intensity.

The shocks which are usually felt in Tokio and Yokohama, as calculated from diagrams, have a maximum acceleration of from 20 to 200 millimètres per second. When this exceeds 300 millimètres we may expect chimneys to be cracked, and slight damage of a like nature done to buildings.

To complete this investigation I have the intention of comparing together the maximum velocity of an earth-particle, as computed from a diagram, with that calculated by the projection or overthrow of a body of known dimension—the impulse being given by the explosion of a charge of dynamite.

An investigation which I described in my last report to the British Association was the determination of the existence of an earth-current at the time of an earthquake. I then stated that a strong current was produced in a land line connected with an earth plate which had been shaken. This confirmed the numerous records which we have of currents

being produced at the time of earthquakes. Another set of records, which we are in possession of, indicate that many earthquakes have been preceded by earth-currents.

If, as we have reason to believe, certain earthquakes are the result of a sudden breaking in the rocky crust of the earth, produced by bending due, for example, to elevatory pressure, it would seem possible that, in consequence of the compressions and extensions to which the rocks are subjected prior to their collapse, electrical phenomena might be produced.

To test the truth of this supposition Mr. T. Gray has undertaken a series of experiments which are not completed. Preliminary results of these experiments seem to indicate that a difference of potential is produced between the two sides of a slab of rock when it is bent.

Report of the Committee, consisting of Mr. R. ETHERIDGE, Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*), *on the Fossil Phyllopoda of the Palæozoic Rocks.*

OF the collections known to contain many of the fossil Phyllopods, those in the British Museum and the Museum of Practical Geology, in London, that of the Woodwardian Museum, Cambridge, and of Owens College, Manchester, have been carefully examined; and sketches have been made of the numerous specimens. Tracings of all the published figures have also been carefully made, to ensure ready collation of the many different forms. Information has been cheerfully communicated by Mr. Homfray, Mr. Valpy, Mr. Marr, and others, who have collected specimens at various times and places.

Time has not yet allowed of our inspection of the Phyllopodous fossils at the Oxford University Museum, nor at the Ludlow, Glasgow, Edinburgh, and other rich museums; but from the type specimens preserved either in London or at Cambridge, we have been able to make the following observations on *Hymenocaris*, *Caryocaris*, and *Lingulocaris*, three of the oldest genera; and the accompanying synopsis indicates our present opinion of the relationship and range of all the genera with which we are acquainted, either by personal inspection or by study of the illustrations and descriptions given by our fellow-workers in North America and elsewhere.

During our study of *Hymenocaris* we found that '*H. ? major*,' Salter, comprised a *Ceratiocaris* possibly matching the Tremadoc specimens assigned to the genus by Mr. Salter; and we have therefore put it under the more authentic of the two Tremadoc species noticed by him.

The Australian *Hymenocaris Salteri*, M'Coy, having been assigned by Mr. Salter to *Caryocaris*, when he was studying that group in 1862, we have regarded it as a member of the latter genus.

With *Caryocaris Marrii*, Hicks, is a specimen associated under the same name in the Woodwardian Museum that proves to be an *Entomidella*; as it differs somewhat from the known species of that genus, it is now named *E. Marrii*. Of the other specimens named *C. Marrii*, some do not differ from *C. Wrightii*, Salter; but one retains the specific name given by Dr. Hicks.

Besides the *Lingulocaris lingulæcomes*, Salter, some casts in the British Museum seem to warrant the adoption of a new name, *L. siliquiformis*, for a different but allied form.

Synopsis of the Genera of the Fossil Phyllopods.

Geological Stage	Genera	Special character	No. of exposed abdominal segments	No. of caudal spines — Styles and stylets of the telson
	I. Carapace Univalve.			
	(I.) Flat Shield.			
	1. *Neither sutured nor ridged along the back.*			
	(A.) Posterior border entire. (Entire behind.)			
Silurian	*Discinocaris*, H.W., 1866	Angular notch*	4 ?	3 ?
? = Raibl beds (Trias, Hallstadt)	*Aspidocaris*, Reuss., 1867	Angular notch* * Round shield.		
Devonian	*Spathocaris*, Clarke, 1882	Angular notch †		
Devonian	*Pholadocaris*, H.W., 1882	Sinuous notch †		
Devonian	*Lisgocaris*, Clarke, 1882	Oblong notch †		
Devonian	*Ellipsocaris*, H. W., 1882	Rounded notch † † These shields differ in shape.		
	(B.) Posterior border slightly notched.			
Devonian	*Cardiocaris*, H. W., 1882	Front notch oblong		
	(C.) Posterior border deeply notched. (Open behind.)			
Silurian	? *Pterocaris*, Barrande, 1872	Both notches angular (test radiately marked)		
Lower Silurian and Devonian.	*Dipterocaris*, Clarke, 1883	Both notches angular		
	2. *Ridged along the back.* (*Like Apus.*)			
Carbonif. & Devon. = ?	*Dithyrocaris*, Scouler, 1843. (*Argas*, Scouler, 1835).	Ridged and sometimes prickled	1, 4, or 6	3
Carboniferous	*Rachura*, Scudder, 1878	(Telson only known)	—	3
	3. *Sutured along the back.*			
Silurian	A. *Aptychopsis*, Barr. (& H. W.), 1872.	Angular notch		
Lower Silurian	B. *Peltocaris*, Salter, 1863	Rounded notch	4 ?	4 ?
Lower Silurian	C. *Pinnocaris*, R. E. Jr., 1878	Slight notch: striæ concentric far back.		
Silurian	D. ? *Crescentilla*, Barr., 1872	Notched before and behind		

Synopsis of the Genera of the Fossil Phyllopods—continued.

Geological Stage	Genera	Special character	No. of exposed abdominal segments	No. of caudal spines — Styles and stylets of the telson
(II.) FOLDED SHIELD, bent along the back (like *Nebalia*), so as to form two side-flaps or attached valves.				
Lingula-flags	1. *Hymenocaris*, Salter, 1853	Smooth	8 or 9	6
Silurian	2. *Dictyocaris*, Salter, 1860	Reticulate	6 ?	3 ?
Silurian	3. ? ('*Cytheropsis testis*,') Barr., 1872.			
Uppermost Devonian or Lowest Carboniferous	4. ? *Protacaris*, Baily, 1872	(Not well known)		
II. CARAPACE BIVALVE; VALVES HINGED. (I.) POD-LIKE.				
Arenig and Lingula-flags	1. *Caryocaris*, Salter, 1862	Pod-like, smooth	—	3 ?
Tremadoc, Silurian, & Devonian (America).	2. *Ceratiocaris*, M'Coy, 1849	Subovate, suboblong, &c.	5, 6, or 7	3
Silurian	3. *Physocaris*, Salter, 1860	Round	5 or 6 ?	
Carboniferous	4. *Colpocaris*, Meek, 1872	Subovate, strongly emarginate at one end (posterior)	—	3
Devonian	5. *Echinocaris*, Whitfield, 1880	Leperditioid	4 (spiny)	3
Silurian	6. *Aristozoe*, Barrande, 1868	Leperditioid		
Silurian	7. *Orozoe*, Barr., 1872	Leperditioid		
Silurian	8. *Callizoe*, Barr., 1868	Leperditioid		
(II.) CONCHIFEROIDAL; probably enclosing all the abdominal segments.				
Tremadoc	1. *Lingulocaris*, Salter, 1866	Modioloid and faintly ridged.		
Carboniferous	2. *Solenocaris*, Meek, 1872	Long and concentrically marked.		
L. Silurian	3. *Solenocaris*, Young, 1869	Oblong, and obliquely ridged and concentrically marked.		
Silurian or Devonian ?	4. *Myocaris*, Salter, 1864	Quadrangular and strongly ridged obliquely.		
Carboniferous	5. *Leaia*, Jones, 1862	Quadrangular and strongly ribbed obliquely, and concentrically marked.		
Silurian ? Devonian Carboniferous Triassic Rhætic Jurassic Neocomian Tertiary ? Recent	6. *Estheria*, Rüppel, 1838	Like a bivalved mollusc, and concentrically marked.		

Hymenocaris, Salter, 1853.

This palæozoic Phyllopod was first noticed and named by Mr. J. W. Salter in the Report of the British Association (Belfast Meeting) for 1852, 'Trans. Sect.' pp. 57, 58. Its very common species *H. vermicauda* was more fully described, with figures, by Salter in the 'Memoirs of the Geol. Survey Great Britain,' &c., vol. iii., 1866, p. 293; t. 2, f. 1–4; t. 4, f. 25. It has been found in the Lower Lingula-flags of North Wales.

The terms of generic description are—

'Carapace ample, semi-oval, narrowed towards the front, curved downward at the sides, but not angularly bent along the dorsal line; no external eyes; antennæ ?; abdomen as long as, or longer than, the carapace; of nine transverse segments, the last with three pairs of unequal lanceolate appendages.'

Hymenocaris vermicauda, Salter, 1853, has its carapace folded or bent along the back, so as to form two symmetrical valve-like sides, somewhat resembling saddle-flaps, obliquely rounded or semi-elliptical below, and with a very slightly convex dorsal line. The curvature of the ventral edge varies in fulness and in obliquity with individuals, and is nearly always modified by the pressure to which the schist containing the fossils has been subjected. The specimens are all flattened; some are lengthened, and some shortened, according to their position relative to the direction of the squeeze; and nearly all are crumpled or 'plaited'[1] with parallel foldings, coarse or fine, at right angles to the line of lateral pressure.

Some of the best preserved individuals measure $\frac{9}{10}$ inch, others 1 inch, and others (imperfect otherwise) even more, along the back line. Those with the first two measurements are $\frac{8}{10}$ inch in height; and their angular length (from antero-dorsal to postero-ventral points) is $1\frac{3}{10}$ inch. Many smaller individuals occur.

The carapace was thin (hence the name = 'membranous'). No definite structure has been observed; but Salter noted 'short wavy lines' on the carapace and the abdominal segments (*op. cit.* p. 294), and a marginal furrow along the posterior border of the valves (p. 293).

Owing to the compressed condition of the schists,[2] it is difficult to define the original outline of the ends of the carapace. The fig. 4 in pl. 2, 'Mem. Geol. Surv.' iii., is a restoration, and its truncate anterior end is a very doubtful feature. The outline given of a specimen shown in fig. 3, *loc. cit.*, is not supported by the specimen itself. The front angle, though often modified or suppressed by the imperfect cleavage of the schist, is sometimes perfect enough to show that it was much sharper than in the fig. 4 referred to above, in which the truncation is probably due to fracture of the specimen taken as the type. The posterior margin usually appears to have sloped downwards and outwards, with a bold ventral curve, but without the elegant sinuous (ogee) bend, under the dorsal angle, which *Ceratiocaris* usually exhibits.

The relative position of carapace and body-segments has been subjected to much interference, between the death and the imbedment of the specimens, from the decomposition of the soft parts or connecting tissues, and the shifting of the harder relics; yet Mr. Salter's determination of the more truncate or wider (higher) end of the carapace being the

[1] Salter, *Quart. Journ. Geol. Soc.*, vol. x., 1854, p. 209; and *Mem. Geol. Surv.* iii. 1866, p. 247, *note*.

[2] Throughout this Report the author denotes by the term *schist* an imperfectly cleaved mudstone, not a *foliated* rock.

hinder margin seems to be well founded, whether the abdomen be still in apposition or not.

The crumpled bed-planes of the schists frequently exhibit crushed body-joints of the *Hymenocaris*; but these relics of the abdominal portion vary much in the number of attached segments. Sometimes four or five, but not uncommonly six or seven, body-joints occur, with or without the telson being apparent. Eight or nine together are less frequent. In one instance (in the Owens College Museum) eleven segments can be counted, besides an obscure telson, in an unattached body lying on a slab containing numerous specimens of carapaces and body-rings of *Hymenocaris* (from Carrig-felen, collected and given by Mr. D. Homfray). In this case, some (five or six), which appear to have been narrower and softer than the others, may have been within the carapace, for they differ from the others in size and distinctness of outline. The crushing and squeeze have rendered even the best and most promising specimens so obscure that much doubt still exists in the observations on this Phyllopod. Mr. Salter determined nine exposed body-rings (*op. cit.* p. 293; but only eight shown in t. 2, f. 4), with one pair of styles and two pairs of stylets attached to the last joint (*op. cit.* t. 5, f. 2). The abdominal joints vary from about $\frac{3}{10}$ to $\frac{4}{10}$ inch in height, sometimes to $\frac{5}{10}$, very rarely to $\frac{6}{10}$ and $\frac{7}{10}$, but in one case to $\frac{8}{10}$ inch, according to size of individuals and the accidental crush.

Hymenocaris vermicauda occurs in the Lower Lingula-flags, especially 'in the upper portions of the true Lingula-flags' (Salter, *op. cit.* p. 293, and 'Catal. Pal. Foss. Cambridge Mus.' p. 10), near Tremadoc, Ffestiniog, Trawsfynydd, and Dolgelly. The particular localities [1] are: the railway-cutting near Wern, not far from Penmorfa; Pentrefelen, west of Penmorfa; Careg-felen; Bryntwr Summerhouse; and especially the hill descending to Penmorfa Church; Moel-y-gest, the hill behind Portmadoc; Borth cove or harbour near Portmadoc; also at Ffestiniog; Gwen-barent (Gwern-y-barcud, *op. cit.* p. 294), Moel-hafod-owen, and other places near Dolgelly; and doubtfully at Pont Seiont, Caernarvon. A specimen in the British Museum is from the 'Upper Tremadoc' schist (or hard shale) of Garth, near Portmadoc.

The rippled flagstones of the Lingula series near Tremadoc, at the village of Y-Felin-Newydd, and near Pentrefelen and Wern, on the Criccieth road, are marked with tracks referred, with good reason, by Mr. Salter to *Hymenocaris vermicauda* ('Quart. Journ. Geol. Soc.' vol. x., 1854, pp. 208–211; and 'Mem. Geol. Surv.' vol. iii. p. 248 and p. 294, pl. 1).

The foregoing observations apply to *H. vermicauda*. Mr. Salter noticed another fossil from the Lingula-flags, which he referred to the same genus in 1873, having, however, designated it *Sacocaris* in 1867 (afterwards spelt *Saccocaris* correctly).

In the 'Catal. Pal. Foss. Cambr.' p. 7, Mr. Salter entered the species as '*Hymenocaris* (*Saccocaris*, Halifax Trans.[2] 1867) *major*, Salter, n.s. A large ovate carapace, strongly emarginate behind, and larger than *H. vermicauda* (see p. 10). Body-segments broad and short, at least in

[1] Mr. David Homfray, who collected the larger portion of the known specimens of this genus, has favoured us with a note of the localities.

[2] This is a mistake for *Report Proceed. Geolog. Polytech. Soc. W. Riding, Yorkshire*, for 1867 (Leeds, 1868). The reference is vol. iv. p. 588, 'On *Sacocaris*: a new genus of Phyllopoda, from the Lingula-flags,' by J. W. Salter, A.L.S., F.G.S.

seven of the anterior ones; appendages not known; *b.* 297. Caen[Caer]-y-coed, near Maentwrog [Lower Lingula-flags]. Mr. D. Homfray. *b.* 297, body-segments of the same. Same locality and donor.' The figure appended in the outside column is *H. vermicauda*, given as a generic type.

In the Woodwardian Museum at Cambridge are three specimens, A/160 (two), and A/174, from the uppermost part of the Lower Lingula-flags at Caer-y-coed quarry, and labelled as belonging to *H. ? major*, Salter.

1. One of them $\left(\frac{A}{160}\right)$ is a large oblong valve measuring $4\frac{2}{10}$ by 2 inches, truncate (with slight convexity of outline) at one end, and obliquely rounded at the other; the greatest convexity of the broad (posterior ?) end being a very little above the median line of the valve, and that of the narrower end considerably above that line. This appears to be a right valve, gently hollow, showing its inside; it is a mere film on the black schist, and is delicately plaited and gently undulate throughout, in lines parallel to the long axis of the valve, cleavage-pressure having compressed and corrugated the surface from edge to edge; and at the posterior (?) end of the valve the margin is barely perceptible, being fringed off by its extremely plaited state, or (in other words) frittered away in longitudinal shreds parallel with the plaiting of the schist, showing, probably, that this end was of thinner consistence than the rounded end. This condition often occurs with the ends of phyllopodous specimens in the Lingula-flags. There are also some irregular concentric lines in the antero-ventral area, caused by the depression of the convexity of the valve. By lateral pressure the specimen must have lost something in height, and has had its length exaggerated. This specimen is evidently the one referred to in the 'Rep. Proc. Geol. Polytech. Soc. W.Y.' iv. p. 589, which was at first thought to be a 'hollow oblong scute, after the manner of *Apus*;' but the 'three distinct ridges on the hinder border' are not at all visible. Though of extraordinary size, this may be regarded as a *Hymenocaris*, after Salter's determination, in the absence of evidence to the contrary. The occurrence of single valves is not uncommon, though the carapace does not appear to have been sutured.

2. The second specimen in the Woodwardian Museum, also marked $\frac{A}{160}$, is of smaller size ($3\frac{1}{10} \times \frac{8}{10}$ inch), narrower, and more silicular in shape; and it has a distinctly *emarginate* posterior end, though this feature can be recognised in the black schist only by reflected light at a certain angle. It is coarsely plaited lengthwise, narrowed (contracted in height), and much lengthened. The *emarginate* or sinuous end is different from that of *Hymenocaris*, and similar to that of *Ceratiocaris*. Nevertheless, it may possibly (though not probably) have been produced by the strong tendency of the schist to take on a state of cleavage, crumpling up the posterior margin by pressure contrary to its direction.

On the other hand, a smaller specimen (marked $\frac{A}{170}$) from Wern, near Portmadoc, in somewhat similar schist, but not 'plaited,' shows a definitely *emarginate*, sinuous, or ogee posterior margin, and thus presents a marked feature of *Ceratiocaris*. This is a posterior moiety of a valve, $\frac{9}{10}$ long $\times$ $\frac{6}{10}$ inch high. As the abdominal part of *Ceratiocaris ? latus*, Salter, and the telson-spines of *C. ? insperatus*, Salter ('Mem. G. S.' iii. pp. 294, 295) come from the Upper-Tremadoc schists, near Portmadoc, we may regard

No. 2 from Caer-y-coed, and $\frac{A}{170}$ from Wern, as belonging probably to *Ceratiocaris*, and possibly belonging to either *C. latus* or *C. insperatus* (if, indeed, these be not parts of one species, as intimated by Salter). The latter being the more distinctly a *Ceratiocaris*, its name is here adopted for the three specimens. This No. 2 from Caer-y-coed has the emarginate border mentioned in the 'Cambridge Catal. Pal. Foss.' p. 7, which is altogether wanting in No. 1, $\frac{A}{160}$.

3. The third specimen in the Woodwardian Museum is $\frac{A}{174}$, consisting of a set of 8 or 9 broad ($\frac{7}{10}$ inch high) abdominal segments, from Caer-y-coed, and mentioned by Mr. Salter with the other two specimens from that locality. These seem to have been crushed laterally, like other specimens that are definitely attached to ordinary *Hymenocaris* valves, and scarcely, if at all, to exceed some of those in dimensions (for instance, $\frac{A}{161}$, Woodwardian Museum, $\frac{6}{10}$ inch; and D $\frac{1}{32}$, Mus. Pract. Geol., $\frac{8}{10}$ inch). It is not large enough for $\frac{A}{160}$ *H. major*, and does not correspond with the body-segment of *Ceratiocaris*.

HYMENOCARIS ? (CARYOCARIS, Salter) SALTERI, M'Coy, 1861.

The references to this Australian species (from Redesdale, Victoria) are given in full in the 'Catalogue of Australian Fossils,' by R. Etheridge, Esq., Jun., 1878, p. 17. There is some uncertainty, however, as to its generic relationship; for in a paper written by Mr. Salter in 1862, and published in the 'Quart. Journ. Geol. Soc.' vol. xix. 1863, pp. 135, &c., after noticing that the Australian Graptolites sent to the International Exhibition in London (1862) were recognisable as belonging to the Llandeilo series, as determined in the north of England, he adds in a footnote (p. 139): 'There is even a crustacean [from the same Australian beds], apparently of the genus *Caryocaris*, which M'Coy has done me the favour to name *Hymenocaris Salteri*.' Thus it is evident that Salter saw one example, if not more, of this Australian species in 1862, and did not regard it as a *Hymenocaris*.

CARYOCARIS, Salter, 1863.

This small pod-like palæozoic phyllopod abounds in the Skiddaw slate (Lower-Llandeilo or Arenig group), at many places near Keswick, as at Braithwaite Brow, where specimens are numerous on many bed-planes; and Mr. Salter mentions Causey Pike and Grassmoor, Cumberland ('Catal. Pal. Foss. Cambridge,' 1873, p. 21). H. Woodward mentions Barff and Longside, 'Cat. Brit. Crust.' p. 70. It has been collected by Mr. J. E. Marr, F.G.S., at the Nantlle tramway, Pont Seiont, near Caernarvon (Upper-Arenig group). See 'Quart. Journ. Geol. Soc.' xxxii., 1876, p. 134. The tramway is here called the 'Wantlle railroad.' The 'phyllopod crustaceans' mentioned at p. 135, and preserved in the Woodwardian Museum, Cambridge, are several specimens of *Caryocaris*, and some small caudal styles which may have belonged to *Caryocaris*, though they resemble somewhat those associated with the Upper-Silurian *Peltocaris* and *Discinocaris* in the Coniston mudstone of Skelgill, also collected by Mr. Marr.

Salter determined *Caryocaris* ('Quart. Journ. Geol. Soc.' xix. p. 139) as

having a 'bivalved carapace (with distinct hinge-pits), rounded anteriorly, subtruncate behind, and with the back and front subparallel. The surface is smooth, or with only oblique wrinkles near the margins, but with no parallel lines of sculpture.' The body and abdominal appendages were unknown to Mr. Salter; but he suggested, in a restoration (*op. cit.* p. 137, fig. 15), a short abdomen, with a lanceolate telson and stylet. Mr. Marr has found, in association with *Caryocaris*, at the tramway bridge crossing the Seiont above mentioned, some small slender spines or pointed styles, from about $\frac{8}{10}$ to $\frac{12}{10}$ inch in length, which do not contradict Salter's ideal figure.

Individuals of CARYOCARIS WRIGHTII, Salter, 1863 (*op. cit.* p. 137, fig. 15, and p. 139), measure $1 \times \frac{3}{10}$ inch (Brit. Mus.), $\frac{12}{10} \times \frac{4}{10}$ inch (Brit. Mus.), and $\frac{13}{10} \times \frac{5}{10}$ ($\frac{2}{55}$, Mus. Pract. Geol.).

The test is smooth and thick, somewhat horny in appearance, often with light purplish tints, rarely black; the ventral and anterior margins are thickened with a raised rim. The anterior moiety is not so much contracted as shown in Salter's illustrations, fig. 15, *loc. cit.*, and the figure at p. 21 'Camb. Catal.'; nor is there a rim to the dorsal margin, as in the first of those figures. The 'hinge-pits' have also escaped our observation as yet. The most perfect specimens are suboblong and elongate, very slightly convex on the dorsal border; more so on the ventral, which is elliptically curved, with the convexity slightly greater in its hinder than in its front moiety; both ends truncate, one end (posterior) rather higher than the other; both vertical, angular at top, and neatly curved below; but sometimes modified in direction and form by compression. Owing to the relative solidity of the valves this fossil is not unfrequently preserved in shape, even when the 'plaiting' or imperfect cleavage of the pressed schist crosses them at various angles. Hence these valves are not nearly so much altered in form in the Skiddaw slates as the *Hymenocarides* are in the Lingula-flags; yet occasionally, when they lie parallel with the superinduced grain of the schist, their ends are frayed out, or 'plaited' into a mere fringe. A very much *crumpled* specimen was figured by Mr. Salter in the 'Geologist,' vol. iv. 1861, p. 74, before he described the genus and species in detail.

CARYOCARIS MARRII, Hicks, 1876 ('Quart. Journ. Geol. Soc.,' vol. xxxii. p. 138).

In the Woodwardian Museum, Cambridge, four specimens, from the Upper-Arenig schists on the Nantlle tramway, are labelled *C. Marrii*, Hicks. 1. One, with a black test, compressed, measures $\frac{6}{10} \times \frac{3}{10}$ inch, and this has been so squeezed that possibly it is now even narrower than it originally was; but the front end is broken and the hinder end is fringed off with the 'plaiting' of the schist. This seems to be *C. Wrightii.* It is somewhat thickened at the ventral edge. 2. A similar, but imperfect, specimen, modified with oblique 'plaiting.' Ventral border thickened. 3. Two imperfect specimens on one slab, one of which, probably 1 inch long, is only $\frac{2}{10}$ inch across (high), and has two obscure depressions across its middle. One end seems perfect; the other is fringed out. This approaches most nearly to Dr. Hicks's description of *C. Marrii.* 4. The other specimen is decidedly an *Entomidella* ($\frac{5}{10} \times \frac{1}{10}$ inch), rather smaller than the Menevian *E. buprestis* (Salter), and thinner or sharper posteriorly in proportion. It may be named *Entomidella Marrii* (Hicks). A similar form occurs in the Skiddaw slate ($\frac{2}{53}$ Mus. Pract. Geol.).

In the Museum of Practical Geology, London, there is a small specimen ($D\frac{1}{30}$, p. 11 of the 'Catal. Cambr. Sil. Foss' 1878), labelled '*Entomidella*, Lingula-flags, St. David's,' but it has no cross furrow, and resembles *Caryocaris* in outline. It measures $\frac{7}{10} \times \frac{2\frac{1}{2}}{10}$ inch, and, though small, may be *C. Wrightii.*

We have already remarked (see above, p. 7) that Mr. Salter recognised a *Caryocaris* among the Australian fossils exhibited at the International Exhibition at London in 1862.

Lingulocaris, Salter, 1866.

This was determined and described as a palæozoic bivalved Phyllopod, from the Upper-Tremadoc schists of Tuhwnt-y-bwlch, Garth, Portmadoc, North Wales, by Mr. J. W. Salter, in the 'Memoirs of the Geological Survey,' vol. iii. (1866), pp. 252, 253, and 294. His description of the generic characters is as follows:—'A thin bivalve crustacean shell, with a generic form like that of a *Modiola* or *Mytilus*, with scarcely prominent beaks, and *no*? hinge-teeth; the surface of the carapace is covered by fine raised concentric lines.' A description of *L. lingulæcomes*, Salter, follows, and this form is figured in pl. 10, figs. 1 and 2. See also the 'Catal. of Cambrian and Silurian Fossils in the Geol. Mus., Cambridge,' 1873, p. 16, with a figure.

In the Woodwardian Museum at Cambridge are two specimens of a bivalve ('A 273'), there labelled '*Mytilocaris lingulæcomes*, Salter,' from the above-mentioned locality, one of which, seemingly representing the outside, but somewhat crumpled longitudinally, approximates in its outline and size ($1\frac{3}{10} \times \frac{1}{2}$ inch $= 32 \times 12$ mm.) to Mr. Salter's restoration (?), fig. 1, pl. 10, and fig. in 'Cat. Cambridge Foss.' p. 16. The other is a less perfect internal cast. Otherwise we have not met with any corresponding specimen.

In the British Museum are casts of the insides of two bivalves ('48654' and another), labelled '*Lingulocaris*'; but, though probably belonging to Mr. Salter's genus here mentioned, they differ much from its first species in outline. They are longer, sharper at one end, and more nearly resembling a pea-pod in shape. This species may be distinguished as *L. siliquiformis.* One specimen (presented by the Rev. J. F. Blake) is from the Upper-Tremadoc schists at Garth Hill, Portmadoc, and the other ('48654') is from the Bale schist at Bwlch-y-Gaseg, near Cynwyd, Corwen, collected by 'J. R.'

In Mr. Salter's figures of *L. lingulæcomes* the furrow (slight as it is), passing obliquely from the umbo backwards to the upper part of the posterior margin is a very interesting feature, being emphasised and duplicated in the oblong and angular *Myocaris*, Salter, from the palæozoic pebbles of the Triassic conglomerate at Budleigh-Salterton in Devon. It is also represented in the oblong *Solenocaris*, J. Young, from the Llandeilo or Caradoc-Bala strata of Penwhapple in Ayrshire, but at a different angle, lower down on the surface, and accompanied with two other shallow furrows radiating from the umbo. These features are not without homologies in another Phyllopod, the Carboniferous *Leaia*, where radiating ridges, equivalent to the convex boundaries of the furrows in the preceding forms, are characteristic of the carapace-valves.

Third Report of the Committee, consisting of Mr. SCLATER, Mr. HOWARD SAUNDERS, *and* Mr. THISELTON-DYER (*Secretary*), *appointed for the purpose of investigating the Natural History of Timor-laut.*

YOUR Committee was disappointed in the result of its application at the Southampton meeting for a further grant of 100*l.* in aid of Mr. Forbes's expedition. The sum of 50*l.* which was placed at its disposal was practically only a re-vote of the grant made at Swansea, which had lapsed. In the meantime Mr. Forbes had been obliged to draw bills upon his friends in London to meet the expenses he had incurred in preparing for the expedition, and the sum of 50*l.* was, therefore, drawn as soon as possible and paid to Mr. Alexander Comyns, who had a power of attorney to act on Mr. Forbes's behalf in London.

When your Committee last reported, it was only able to state that Mr. Forbes had reached Amboina in May of 1882, and was on the point of starting for the Tenimber Islands on the first practicable opportunity. He effected his departure after some delay, and in October following a letter was received from him, from which the following is an extract:—

'On board the s.s. "Amboina," at the Aru Islands:
'July 12, 1882.

'Dear Mr. Dyer,—I write you a note to state that to-morrow morning I hope to be deposited, bag and baggage, at Larat, the small island facing the mainland of Timor-laut, on the E. side.

. . . .

'The steamer was delayed three weeks on its voyage prior to its arrival in Amboina, otherwise I should have been three weeks ago on the island of my destination.

'From all accounts received on the coast of New Guinea and at Kè, as well as here, the natives are very well disposed, and I am very sanguine of a successful termination to my journeyings there. I hope to despatch some part of my collections about the middle of September.

'I am, yours very sincerely,
(Signed) 'H. O. FORBES.'

In December following your Committee were gratified at receiving the following further letter from Mr. Forbes, stating that he had succeeded in a great measure in accomplishing his mission, though not without much difficulty and even serious sacrifice of health:—

'Amboina: October 11, 1882.

'Dear Mr. Dyer,—I have only just time to write you a line to inform you of my return from Timor-laut a couple of days ago, having been compelled to leave on account of sickness and of the hostility of the natives of the neighbouring villages, from whom nightly an attack was threatened. We all suffered greatly from fever, and even now I am writing in the midst of a severe attack.

'Extended movements were impossible, so that my botanical collections are not very extensive, but the ornithological and anthropological

parts are very good. I am now engaged in packing all up for despatch, and hope to send them off soon.

'My intention is to return to Timor-laut in three days more, if my health will permit, the Government steamer leaving then for the Tenimber Islands. I shall settle in some quieter spot than Ritabel. A full report of this interesting country will be sent to you by next mail. One of the singular facts I found is the immense herds of wild buffalo existing on the mainland of the island. They must have, of course, been introduced, but by whom and how long ago is an interesting question. I was unable to get a specimen, unfortunately.

'My wife, who accompanied me, aided me greatly, so that, when I was down with fever—and the fever is of extreme severity—work was still able to go on.

. . . .

'I am, yours very truly,
(Signed) 'HENRY O. FORBES.'

In the month of January following a box containing seventy bird-skins was received from Mr. Forbes, with the note, 'This first instalment of birds is a rough selection, which, probably, may contain new species.' The collection was examined by Mr. Sclater, who communicated an account of it to the meeting of the Zoological Society on February 20. The species were fifty-five in number, sixteen of which were described in the paper as new to science. 'The general facies of the avifauna, as thus indicated, was stated to be decidedly Papuan, with a slight Timorese element, evidenced by the occurrence of certain species of *Geocichla* and *Erythrura*, while the new one (*Strix sororcula*) was apparently a diminutive form of a peculiar Australian species.'

About the same time your Committee received from Mr. Forbes a detailed report of his proceedings in Timor-laut. This was an extremely interesting document, but dealt principally with ethnographical details. Your Committee, therefore, decided that it should be communicated at once to the Anthropological Institute; and this Mr. John Evans, Treasurer of the Royal Society and Vice-President of the Institute, very kindly undertook to do. The paper was read at the meeting on March 13, and has since been published in the 'Journal' of the Institute.

In February the bulk of Mr. Forbes's collections reached Kew in four cases. They contained an extremely complete ethnographical collection, a further collection of birds, a collection of twelve crania and specimens of human hair, and a miscellaneous zoological collection. Your Committee decided that a selection from the ethnographical collection should be handed to Mr. Franks, keeper of the Department of Ethnography in the British Museum; that the additional birds should be examined by Mr. Sclater, and that the miscellaneous zoological collections should be sent to the zoological department of the British Museum to be selected from. This was accordingly done. A series of the ethnographical specimens was sent to the meeting at the Anthropological Institute to illustrate the reading of Mr. Forbes's report, and a description of these drawn up by Mr. C. H. Read is printed as an appendix to the paper in the 'Journal' of the Institute. Professor Flower, who presided on the occasion, also stated that 'the results of a cursory examination of the twelve crania which Mr. Forbes had collected were that eight were brachycephalic, and of decidedly Malay type; one was dolichocephalic, prognathous, and with

large teeth, indicating Papuan or Melanesian affinities; and the other three were more or less intermediate. This is what might have been expected on the border-land of two distinct races; but the great preponderance of the first-named was very marked. Nearly all showed signs of artificial flattening of the occipital region.'

At the meeting of the Zoological Society on April 17, Mr. Sclater read a second paper on the additional birds collected by Mr. Forbes in the Tenimber group. 'The avifauna of the group, as indicated by Mr. Forbes's collection, contained fifty-nine species, of which twenty-two were peculiar to these islands.'

At the meeting of the same society on May 1, Mr. W. F. Kirby reported on the small collection of Hymenoptera (five new species were described) and of Diptera sent home by Mr. Forbes. On June 5 a communication was read from Mr. A. G. Butler, containing an account of the twenty-three Lepidoptera. These comprised 23 species of Lepidoptera; the butterflies were well preserved, the moths in poor condition. Mr. Butler described 10 new species. Deducting wide-ranging forms the following is his analysis of the characteristic species:—'Indo-Malayan, 2; Austro-Malayan, 10; Australian, 3. The only surprising thing in this distribution is the preponderance of Timor over Aru or New Guinea forms; the species characteristic of that island being only equalled by those from Aru, New Guinea, and Amboina combined.' Mr. Boulenger also reported, at the same meeting, upon the reptiles and batrachians. Two new species were described—the one a lizard of the Australian genus *Lophognathus*, and the other a snake of the Indian genus *Simotes*. 'The snake was of special interest, as no species of the genus *Simotes* had hitherto been previously known to occur eastward of Java.'

Some discussion having taken place with Mr. Comyns, Mr. Forbes's representative in England, as to the way the Timor-laut collections should be dealt with, your Committee proposed to Mr. Comyns, as the condition upon which any grants of money made to it should be handed over to Mr. Forbes, that of the collections made by him, 'both zoological and botanical, the first complete set is to be placed at the disposal of the Committee.' To this Mr. Comyns agreed. He subsequently raised the question as to whether the ethnographical collections came within the terms of this agreement. Your Committee thought the point doubtful. At the same time they were very anxious that the fruits of Mr. Forbes's expedition should be accessible in public museums, and should not be dispersed in private hands. It was ultimately agreed that a selection from the ethnographical collection should be purchased for the British Museum; and the Royal Society, at the instance of Mr. John Evans, very liberally voted the sum of 40*l.*, which was fixed by Mr. Franks as a reasonable price for the collection. A few objects were selected as suitable for the Museum of Economic Botany at Kew, and these were purchased from Mr. Comyns as a set-off against the expenses incurred for the freight of the whole collections. The duplicates of the ethnographical and other collections were all duly handed over to Mr. Comyns.

Mr. Forbes's botanical collections have not at present reached Kew; but there is reason to fear, from a variety of circumstances beyond Mr. Forbes's control, that they will prove of inferior interest to the other collections made by him.

Your Committee understand that the total expense of Mr. Forbes's

expedition has amounted to 300*l*. Towards this he has now received assistance from the British Association and the Royal Society to the amount of about 190*l*. He may to some moderate extent recoup himself further by the sale of duplicates.

Your Committee, on reviewing what has been accomplished since its first appointment, are of opinion that the Association may fairly congratulate itself on the successful result of an expedition carried out in a most efficient, but most economical way; it would probably not have been undertaken at all without its timely assistance. They believe that the scientific results obtained do not fall short of their original anticipations. Timor-laut,[1] as its name indeed implies, is the last link to the east of the Malayan insular chain, and the commingling of the forms of life belonging to the great geographical regions, the Malayan and the Papuan, which it exhibits, is of peculiar interest, and merits the most careful study.

Your Committee believe that the Association would not wish that a scientific man like Mr. Forbes, who has carried out a task of so laborious and, indeed, perilous a kind should be dealt with in anything short of a reasonably liberal way.

Having regard, therefore, to the fact that the botanical collections have still to be discussed, and the anthropological and ethnographical collections more fully worked out, your Committee ask for their re-appointment, and that a sum of 100*l*. should be placed at their disposal. The grant of 50*l*. made at Southampton was, as already stated, practically only a re-vote of the grant made at Swansea, which lapsed.

Mr. Forbes will be present at the Southport meeting.

Report of the Committee, consisting of Lieut.-Col. GODWIN-AUSTEN, Dr. G. HARTLAUB, Sir J. HOOKER, Dr. GÜNTHER, Mr. SEEBOHM, *and* Mr. P. L. SCLATER (*Secretary*), *appointed for the purpose of investigating the Natural History of Socotra and the adjacent Highlands of Arabia and Somali Land.*

THE balance left in the hands of the Committee last year was 143*l*. 13*s*. 2*d*. Together with interest since accrued it now amounts to 145*l*. 1*s*. 10*d*. There has been no further sale of the duplicates, but a few specimens of some of the land and fresh-water shells still remain on hand for disposal.

Professor Bayley Balfour's labours on the botanical collection made in Socotra are nearly brought to a close, and the results will shortly be published in a volume of the 'Transactions' of the Royal Society of Edinburgh. The value and completeness of this memoir will be much increased by the additional specimens subsequently obtained in Socotra by Dr. Schweinfurth, which have been lent to Professor Balfour by the collector.

[1] 'Laut' signifies 'eastward' or 'seaward,' and refers to the position of Timor-laut in relation to Timor.

The fresh-water shells collected by Professor Balfour have been described by Lieut.-Col. Godwin-Austen, in a paper read before the Zoological Society of London in January last, and published in the first part of their 'Proceedings' for the present year.

The Diatomaceæ have been examined by Mr. Kilton of Norwich, and described in a paper which will be read before the Linnean Society of London during their next session.

These two papers have to be added to the list of papers on the natural history of Socotra resulting from Professor Balfour's expedition specified in the last report of the Committee.

The Committee are of opinion that these contributions, along with the botanical memoir of Professor Balfour (on what was naturally the richest part of the collection, and on which most of his limited time in Socotra was spent), taken together have yielded a rich return for the several sums of money granted to them by the Association. When the aid of the Association was first asked for this purpose an almost absolute ignorance of the Fauna and Flora of Socotra existed. Now both Fauna and Flora are at all events generally known, and their relationships with those of the mainland and adjoining islands have been more or less accurately pointed out. Although a second expedition to Socotra would be desirable, and the exploration of the adjacent highlands in Arabia and Africa would certainly add much to our knowledge, there seems to the Committee little prospect of accomplishing these objects under the present state of circumstances in the East. The Committee have therefore repaid to the Treasurer of the Association the above-mentioned balance of 145*l.* 1*s.* 10*d.*, less a small sum deducted for petty expenses. The Committee, however, trust that this amount may be again placed at their disposal upon a future occasion should circumstances arise which would encourage them to undertake another expedition.

Report of the Committee, consisting of Sir JOSEPH HOOKER, Dr. GÜNTHER, Mr. HOWARD SAUNDERS, *and* Mr. P. L. SCLATER (*Secretary*), *appointed for the purpose of exploring Kilimanjaro and the adjoining mountains of Eastern Equatorial Africa.*

1. In November last Sir Joseph Hooker communicated with Dr. Schweinfurth, now residing at Cairo, informing him of the wish of the Committee, that he should be furnished with information respecting the projected expedition, and expressing a hope that he would volunteer to lead it. Dr. Schweinfurth replied to Sir J. Hooker on November 25 that he regretted to say his services were not available.

2. Upon this Sir Joseph Hooker, as authorised by the Committee, wrote, on December 8, to Dr. Watt, of the Bengal Education Department, Calcutta, a traveller and collector in all parts of India, who had lately returned from accompanying, as botanist, a survey of Munnipore. Dr. Watt having professed his willingness to undertake the expedition, Sir J. Hooker wrote officially, on March 21, to the Secretary of State of India in Council, requesting that Dr. Watt's services might be placed at the

disposal of the Committee. This was granted on May 9, but on terms so prejudicial to Dr. Watt's interest as an officer in the Government service, that he could not avail himself of the commission.

3. In the meanwhile Dr. Watt was appointed to duties in connection with the International Exhibition to be held in Calcutta in 1884. This appointment would necessarily postpone Dr. Watt's departure to Africa until 1885.

4. Considering the great probability of further obstacles arising to prevent Dr. Watt from undertaking the conduct of the expedition, in case he should again come forward, we think that any reasonable hope of securing his services must be abandoned, and that further steps should be taken to secure a proper leader.

5. With this object Sir J. Hooker has placed himself in communication with Capt. Maloney, late Administrator of the Gold Coast, respecting a medical officer in the Colonial Service, of whose ability and industry Capt. Maloney has spoken in very high terms, and who, we have reason to hope, will undertake the expedition. Should this not be the case we shall do our best to find another fit person for the purpose.

6. Under these circumstances the Committee trust that the sum of 500*l.*, voted at Southampton, which has been returned to the Treasurer of the Association in accordance with the regulations, may be revoted to them at the present meeting.

Report of the Committee, consisting of Mr. JOHN CORDEAUX (*Secretary*), Mr. J. A. HARVIE-BROWN, Mr. P. M. C. KERMODE, Professor NEWTON, Mr. R. M. BARRINGTON, *and* Mr. A. G. MORE, *reappointed at Southampton, for the purpose of obtaining (with the consent of the Master and Brethren of the Trinity House, and the Commissioners of Northern and Irish Lights) observations on the Migration of Birds at Lighthouses and Lightships, and of reporting on the same.*

THE General Report[1] of the Committee, of which this is an abstract, comprises the observations taken at lighthouses and lightvessels, and a few special land stations, on the east and west coasts of England and Scotland, the coasts of Ireland, Isle of Man, Channel Islands, Orkney and Shetland Isles, the Hebrides, Faroes, Iceland, and Heligoland, and one Baltic station—Stevns Fyr on Stevns Klint, Zealand, for which the Committee is indebted to Professor Lütken, of Copenhagen. Altogether 196 stations have been supplied with schedules and printed instructions for registering observations, and returns have been received from about 123—a result which is very satisfactory, showing as it does the general interest taken in the work, and the ready co-operation given by the lightkeepers in assisting the Committee.

The stations returning the best-filled schedules are: on the East

[1] Report on the Migration of Birds in the Spring and Autumn of 1882. West, Newman, & Co., 54 Hatton Garden, London, E.C.

Coast of Scotland, the Pentland Skerries, nine, Sunburgh Head, four, Bell Rock, three, and Isle of May no less than nineteen; on the east coast of England, Farne Islands, eleven, and after this Flamborough Head, Spurn Point, and several of the lightvessels off our south-east coast. On the Irish coast the best returns have come in from the Tuscar rock on the Wexford coast. This is the extreme south-eastern point of Ireland, and the nearest land to the Welsh coast, and seems well situated for observations.

Taken as a whole, and comparing them with reports from the English coasts and elsewhere, it is evident that Ireland lies comparatively out of the track of migrants, and its western stations are especially poor. These have, however, much interest in themselves, in the notices of the movements and habits of the various seafowl frequenting that wild district.

The entries in the schedules returned to us have, as might be expected, special reference to the movements of various species of land-birds, yet many observations will be found in the general report, on the going and coming of seafowl, which dwell for a season on the cliffs, islands, and outlying rocks off our coasts, their mode of feeding, nesting, &c. These are valuable as made by those who actually live amongst the birds, and have ample opportunity and leisure to observe their habits and report thereon. Thus the presence of the gannet all around the coast of Ireland during the breeding season points to the conclusion that a considerable proportion of the birds seen do not breed. The Little Skellig rock, off the Kerry coast, is the only Irish breeding-place of this species, and when visited by Mr. Barrington in 1880 there were scarcely thirty pairs nesting there.

As in preceding years, the line of autumn migration has been a broad stream from east to west, or from points south of east to north of west and covering the whole of the east coast. In 1880, to judge from the returned schedules, a large proportion of the immigrants came in at the more southern stations; in 1881 they covered the whole of the east coast in tolerably equal proportions; but in 1882 the stations north of the Humber show a marked preponderance of arrivals. Altogether a vast migration took place this year upon our east coast, the heaviest waves breaking upon the mouth of the Humber, Flamborough Head, the Farne Islands, Isle of May at the entrance to the Firth of Forth, and again, after missing a long extent of the Scotch coast, at the Pentland Skerries.[1] The Bell Rock also came in for a share, although apparently a much smaller one than the Isle of May. The easterly winds prevailed all along our east coasts, generally strong to gales, and the succession of south-easterly and easterly gales in October, between the 8th and 23rd, occurring as they did at the usual time of the principal migration, brought vast numbers of land birds to our shores. From the Faroes in the north to the extreme south of England this is found to have been the case.

Although migration—that is, direct migration—on our east coast, is shown to have extended over a long period, commencing in July and continuing, with but slight intermissions, throughout the autumn and into

[1] The absence of returns, year by year, on the Scotch coast between the Bell Rock and Dunnet Head, embracing ten important lighthouses, is remarkable, not a single statistic of direct value as regards general migration having, so far, rewarded our inquiries. No communications, positive or negative, have been received from these stations, except a brief return from Girdleness.

the next year to the end of January, yet the main body of migrants appear to have reached the east coast in October, and of these a large proportion during the first fortnight in the month. From the 6th to the 8th inclusive, and again from the 12th to the 15th, there was, night and day, an enormous rush, under circumstances of wind and weather which, observations have shown, are most unfavourable to a good passage. During these periods birds arrived in an exhausted condition, and we have reasons for concluding, from the many reported as alighting on fishing smacks and vessels in the North Sea, that the loss of life must have been very considerable. Large flights also are recorded as having appeared round the lanterns of lighthouses and light-vessels during the night migration. From the 6th to the 9th inclusive strong east winds blew over the North Sea, with fog and drizzling rain, and from the night of the 12th to 17th very similar weather prevailed. Mr. W. Littlewood, of the Galloper lightship, forty miles south-east of Orfordness, reports that, on the night of October the 6th, larks, starlings, tree-sparrows, titmice, common wrens, redbreasts, chaffinches, and plovers were picked up on the deck, and that it is calculated that from five to six hundred struck the rigging and fell overboard: a large proportion of these were larks. Thousands of birds were flying round the lantern from 11.30 P.M. to 4.45 A.M., their white breasts, as they dashed to and fro in the circle of light, having the appearance of a heavy snowstorm. This was repeated on the 8th and 12th, and on the night of the 13th 160 were picked up on deck, including larks, starlings, thrushes, and two redbreasts. It was thought that 1,000 struck and went overboard into the sea. It is only on dark rainy nights, with snow or fog, that such casualties occur; when the nights are light, or any stars visible, the birds give the lanterns a wide berth.

Undoubtedly the principal feature of the autumn migration has been the extraordinary abundance of the gold-crested wren. The flights appear to have covered not only the east coast of England, but to have extended southward to the Channel Islands and northward to the Faroes (see Report, East Coast of Scotland). On the east coast of England they are recorded at no less than twenty-one stations from the Farne Islands to the Hanois, L.H., Guernsey, and on the east coast of Scotland at the chief stations from the Isle of May to Sunburgh Head (at which latter station they have rarely been seen in previous years). Mr. Garrioch, writing from Lerwick, says: ‘In the evening of the 9th of October my attention was called to a large flock of birds crossing the harbour from the island of Bressay, and on coming to a spot on the shore where a number had taken refuge from the storm I found the flock to consist of gold-crests and a few fire-crests [1] amongst them; the gold-crests spread over the entire island and were observed in considerable numbers till the middle of November.’ The earliest notice on the East Coast is August 6th, the latest November 5th, or ninety-two days; they arrived somewhat sparingly in August and September, and in enormous numbers in October, more especially on the nights of October 7th and 12th, at the latter date with the woodcock. This flight appears to have extended across England to the Irish coast, for on the night of the 12th a dozen struck the lantern of the Tuscar Rock Lighthouse, and on the night of

[1] The distinction between the two species had been clearly pointed out to Mr. Garrioch.

the 13th they were continually striking all night. During the autumn enormous numbers crossed Heligoland, more especially in October. On the night from the 28th to the 29th Mr. Gätke remarks: 'We have had a perfect storm of gold-crests, perching on the ledges of the window-panes of the lighthouse, preening their feathers in the glare of the lamps. On the 29th all the island swarmed with them, filling the gardens and over all the cliff—hundreds of thousands. By 9 A.M. most of them had passed on again.' Not less remarkable was the great three days' flight of the common jay, past and across Heligoland, on the 6th, 7th, and 8th of October. Thousands on thousands, without interruption, passed on overhead, north and south of the island too, multitudes like a continual stream, all going east to west in a strong south-easterly gale. It would have been interesting if we had been able to correlate this migration of jays with any visible arrival on our English coast, but in none of the returns is any mention made of jays. Subsequently we have received numerous notices of extraordinary numbers seen during the winter in our English woodlands. This seems especially to have been the case south of a line drawn from Flamborough Head to Portland Bill in Dorset. Additions and unusual numbers were also observed at Arden on Loch Lomond side.

Immense numbers of the hedge-sparrow passed over Heligoland in October, more especially on the 6th, 7th, and 8th. It is curious that on the 8th of the same month they swarmed in astonishing numbers both at Spurn Point and in North-east Lincolnshire.

Woodcocks arrived on the east coast on the night of October 12th, or early morning of the 13th. Wind east, strong, fog and drizzling rain. On the morning of the 13th they are recorded from ten stations, covering 350 miles of coast, from the Isle of May to Orfordness.

Some species which occur with tolerable regularity on the east coast, have during the autumn of 1882 been remarkably scarce. Very few short-eared owls have been seen in England or Scotland. The common linnet and twite have also been very scarce, and the same remarks apply to Heligoland.[1]

The returns show very clearly that the spring lines of migration followed by birds are the same as those in the autumn, but of course in the reverse direction—from W. and N.W. to E. and S.E. Another point worth noting is the occurrence of many species in spring at the same stations frequented by the species in autumn. Thus double records occur at the Mull of Galloway, Bell Rock, Isle of May, as well as at some English stations.

As this is the fourth report issued by the Committee, we may perhaps, with the mass of facts at our disposal, be expected to draw deductions which, if they do not explain, may serve at least to throw some light on the causes influencing the migration of birds. We might reasonably reply that the work undertaken by us was not to theorise, or attempt explanations, but simply to collect facts and tabulate them; this we have endeavoured to do, in the shortest and simplest manner consistent with accuracy of detail. There is, however, one circumstance which can scarcely fail to present itself to those who have gone carefully into the reports issued by the Committee, namely, the marvellous persistency with which, year by

[1] There was a vast rush of the common linnet at the Isle of May from the 9th to the 23rd of October.

year, birds follow the same lines, or great highways, of migration, when approaching or leaving our shores. The constancy of these periodical phenomena is suggestive of some settled law or principle governing the movement. It is clearly evident, from the facts already at our disposal, that there are two distinct migrations going forward at the same time, one the ordinary flow in the spring and ebb in the autumn across the whole of Europe. A great migratory wave moves to and from the nesting-quarters of the birds, in the coldest part of their range, north-east in the spring and south-west in the autumn. Quite independent of this there is a continual stream of immigrants, week by week and month by month, to the eastern shores of these islands, coming directly across Europe from E. to W., or more commonly four points south of east to north of west, and the reverse in the spring. These immigrants are mainly composed of those common and well-known species which annually make these islands their winter quarters, and, as a rule, take the place of our summer birds. They come in one broad stream, but denser on some special lines or highways than others. Cutting the line of ordinary migration at nearly right angles, one flank brushes the Orkney and Shetland Isles, pouring through the Pentland Firth, even touching the distant Faroes; the southern wing crosses the Channel Islands, shaping its course in a north-westerly direction to the English coast.

In conclusion your Committee would take this opportunity of once more expressing their best thanks to the Master and Brethren of the Trinity House, the Commissioners of Northern Lights, and the Commissioners of Irish Lights, for their ready co-operation and assistance, through their officers and men, in the inquiry.

Your Committee respectfully request their reappointment, and trust that the Association will enable them to continue the collection of facts.

Report of the Committee, consisting of Dr. PYE-SMITH, Professor M. FOSTER, Professor HUXLEY, Dr. CARPENTER, Dr. GWYN JEFFREYS, Professor RAY LANKESTER, Professor ALLMAN, *and* Mr. PERCY SLADEN (*Secretary*), *appointed for the purpose of aiding in the maintenance of the Scottish Zoological Station.*

DURING the past year the station has been removed from Oban to the east coast of Scotland, where it is again erected upon the northern shore of the Moray Frith, within a few miles of the site which it occupied in 1880–1 when the researches on the locomotor system of echinodermata were conducted.

Owing to an unfortunate oversight on the part of Dr. M. Foster the grant of 40*l*., which had been awarded to the station by the British Association, was not applied for in due time, and in consequence when it was applied for was found to have lapsed. The researches which were contemplated when the station was again erected on the shore of the Moray Frith were for this and for other reasons unavoidably postponed. Hence the only work which has been carried on at the station during the

past year has been that which was undertaken by Professor Schäfer, on the perivisceral fluid of echinus, published in the 'Proceedings of the Royal Society.'

Arrangements have now been made for the prosecution of several interesting lines of research, and there is no doubt that next year, should the British Association continue its pecuniary aid to the institution, a more satisfactory report will be issued.

Report of the Committee, consisting of Professor RAY LANKESTER, Professor NEWTON, Professor HUXLEY, Mr. P. L. SCLATER, Professor ALLMAN, Professor M. FOSTER, Mr. A. SEDGWICK, *and* Mr. PERCY SLADEN (*Secretary*), *appointed for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples.*

YOUR Committee, in submitting their Report on the Zoological Station at Naples, have again the pleasure of drawing attention to the steady progress and continued prosperity of this excellently managed institution. That no diminution has taken place in its popularity amongst naturalists is fully proved by the fact that a greater number have worked at the station during the past twelve months than in any previous year. Since the presentation of the last report two additional tables have been engaged; America, represented by the Williams College, Massachusetts, having secured a permanent place by contract for several years; whilst Belgium has taken a second table for a year, specially for the prosecution of botanical investigations.

The Laboratory.—Amongst recent acquisitions in this department may specially be mentioned a large aërating apparatus capable of supplying about seventy small tanks and breeding aquaria simultaneously; an adjunct which has already proved of great value in embryological and developmental investigations. The equipment of the tables keeps pace as heretofore with the requirements of the improved methods of scientific research. Several important improvements in this direction have been made by members of the staff of the station, as, for example, the already popular mode of manipulating serial sections detailed by Dr. Giesbrecht in the 'Zoologischer Anzeiger' for 1881, and more recently the improvement of Jung's microtome, described in the last part of the 'Mittheilungen' of the station.

The Collecting Department.—This department has received an important adjunct in the acquisition of a second steamboat. The large original steam yacht is still employed, as formerly, for dredging and for more extended excursions, whilst the new and smaller steamboat is admirably suited for the purpose of visiting the boats of fishermen in the bay who are willing to collect specimens for the station on their own account. Fishermen employed in this way receive from the station the necessary glass or other vessels in which to preserve, until fetched away by the steamer, whatever they may capture likely to prove interesting to zoolo-

gists. The new steamboat is also frequently used for towing the rowing and the diving boats.

In the course of next year the whole collecting department will be placed under the management of a scientifically qualified member of the staff, who will be especially engaged for this purpose. This official will direct his attention to the investigation of the fauna, and with this object in view will resume the keeping of the various lists and records bearing on these enquiries, which have unfortunately been interrupted for some time, since the previous official by whom they were undertaken left the station.

Preserved Specimens.—The number of prepared specimens sent out during the past year has considerably increased in comparison with the previous year. Experiments in new methods of preservation are continually prosecuted, and most satisfactory results are constantly being attained. Mention may here be made that the station is represented in the International Fisheries Exhibition, now being held in London, by a collection of these preparations; and of these it may be said impartially that never has a fauna furnished a more perfect, and at the same time more beautifully preserved, series of organisms.

Microscopic Preparations.—The demand for microscopic preparations has diminished in comparison with last year. As this branch of the Institution has hitherto failed to a certain extent to fulfil the expectations originally entertained, the attitude of the Directorate in respect thereto is at present of a somewhat passive nature, and it will be a subject for enquiry and ultimate decision whether this department can be further developed, and, if still maintained, whether any reform is necessary to promote its efficiency.

The Aquarium.—The aquarium continues to be an important means of enlisting the sympathy and interest of the general public in behalf of the station and the biological sciences. To attain this end nothing is left undone which can be undertaken without prejudice to the establishment in general.

During the course of the past year an English 'Guide' has been added to those already existing in the German, French, and Italian languages; and an atlas, comprising 250 figures of the most interesting animals, which will supplement the 'Guides,' is at present in the press.

The number of visitors to the Aquarium is as great as in previous years.

The Publications of the Station.—The various works undertaken by the station show steady progress.

1. Of the 'Fauna und Flora des Golfes von Neapel' the following monographs have been published:—

For 1880.	I.	C. Chun, *Ctenophoræ*, 313 pp., 18 pl.
	II.	C. Emery, *Fierasfer*, 76 pp, 9 pl.
For 1881.	III.	A. Dohrn, *Pantopoda*, 252 pp., 17 pl.
	IV.	Graf Solms-Laubach, *Corallina*, 64 pp., 3 pl.
For 1882.	V.	B. Grassi, *Chetognati*, 126 pp., 12 pl.
	VI.	P. Mayer, *Caprellidæ*, 201 pp., 10 pl.
	VIII.	G. Berthold, *Bangiaceæ*, 28 pp., 1 pl.

For 1882 there are also allotted to be published:—

VII. R. Valiante, *Cystoseire.*
IX. A. Andres, *Attinie* (parte 1ma.)

Both these monographs are in the press, and will appear in a few months. The last named is illustrated with thirteen coloured plates.

For 1883 the following are allotted, subject, possibly, to some little alteration:—

W. Uljanin, *Doliolum.*
A. Andres, *Attinie* (parte 2da.)
A. Lang, *Polycladæ* (Planariæ).
P. Falkenberg, *Rhodomeleæ.*
G. Berthold, *Cryptonemiaceæ.*

The plates of several of these monographs are in the hands of the lithographer, and the printing of the text of Dr. Lang's monograph has already commenced. This latter will appear before the close of the year. The number of monographs announced for following years has increased, and besides those previously mentioned there are in preparation monographs on Radiolaria, Spongia, Siphonophora, Gorgoniidæ, Amphictenidæ, Polygordius, Copepoda pelagica, Amphipoda.

2. Of the 'Mittheilungen aus der Zoologischen Station' there have been published vols. i.–iii., and vol. iv., parts i.–iii.; part iv. is now in the press, and for vol. v. a series of works are announced.

3. The 'Zoologischer Jahresbericht.' The division of the 'Jahresbericht' into four sections, which was adopted in 1880, has been retained for the 1881 'Bericht,' and the whole will occupy about the same bulk,—namely, over 1,200 pp. The number of referees engaged in the work has been augmented; and Professor J. V. Carus, who edited the vols. for 1879–80, has made over the editing of the second section (Arthropoda) to Dr. P. Mayer. The first three sections of the 'Bericht' for 1883 are in the press, and will appear in the course of some months. The whole 'Bericht' for 1883 will be edited by the zoological station.

The Library.—The library, as in previous years, has been augmented by presentations from authors, from several publishers, and from a number of scientific institutions, as well as by numerous purchases. Furthermore, a great number of new journals have been procured on account of the 'Jahresbericht.'

The publication of a supplement to the library catalogue is deferred this year, as it will be desirable to issue a complete catalogue next year.

The British Association Table.—During the past year the Association table has been used by Mr. J. T. Cunningham, whose occupancy extended over a term of six months, by special permission of your Committee. The report which Mr. Cunningham has furnished of his investigations is appended below. The usual lists and detailed information courteously supplied by the staff of the zoological station are also appended.

Two applications for the use of the table during the coming year have been received by the Committee, and from both of the applicants work of an important character may be anticipated.

With the present facts before them, and every assurance of the continued utility of the Association table, and of the advantages afforded by it to British naturalists, your Committee strongly recommend the renewal of the grant.

I. *Report on the Occupation of the Table by Mr. J. T. Cunningham.*

I arrived at Naples on Sunday, November 5, 1882. The Committee of the British Association had, in accordance with my request, kindly given me permission to occupy their table for six months. Everything was ready for me to commence work at once, and during the whole of my stay I had more and more cause to admire the perfection of the working arrangements of the station and the courtesy and care with which the staff provided for the wants of the numerous zoologists at work in the laboratory.

I went to Naples with the intention of working out certain points in the anatomy of the Mollusca, and if possible of obtaining some light on their phylogenetic history by a study of their organogeny. These matters occupied the greater part of my time, although I of course availed myself of the unique opportunities of the station for the study of marine forms in general, and of many cases of development. For example, I studied the artificial fertilisation and subsequent development of species of Echinoidea, and spent many hours over the Radiolaria, Medusæ, Siphonophora, and numerous larval forms which occur in bewildering profusion in the product of the surface-collecting, known in the station as 'Auftrieb.'

I also took up to a certain extent the anatomy of the Gephyreans and of the Siphonostomata, in order to compare the former with the forms most nearly approaching them among the Chætopoda. In the anatomy of Siphonostoma and of Stylarioides I found there were several interesting points for investigation, and I was sorry that I could not make my researches on them more complete.

One of the points in molluscan anatomy which I succeeded in working out was the relation of the renal organs to the pericardium in Patella: I found that each renal organ had an independent opening into the pericardial cavity. I also studied the form, relations, and histology of the kidney (triangular gland) in the genus Aplysia, and prepared a description of the organ for the 'Mittheilungen' of the station.

For the development of the organs in Mollusca I took nearly all the material I could get, including the ova of the Cephalopoda. I found it extremely difficult to obtain satisfactory preparations which would clear up the doubtful points in the organogeny either of the Cephalopoda or the Gasteropoda, which were the two groups I chiefly studied. Up to the time I left Naples I had not obtained any definite results.

I gave up the table a few days before the end of April 1883; it is with much pleasure that I thank the Committee for the privilege they granted me; the period of my occupation of the table was most agreeable and profitable to me.

I must also express here my deep indebtedness to the kindness and friendly support which I received from Dr. Dohrn and all the other members of the staff of the station. I was permitted to accompany collecting expeditions and to become familiar with the whole organisation and working of the laboratory and aquarium. The station is an immense advantage to zoology in general and to all European zoologists, and the Association deserves the gratitude of English biologists for holding a table in its laboratory.

II. *A List of the Naturalists who have worked at the Station from the end of June* 1882 *to the end of June* 1883.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
210	Dr. Traustedt	Zoological Station	May 13, 1882	July 15, 1882
211	Dr. C. Crety	Italy	July 10 "	Oct. 2 "
212	Prof. F. Gasco	Italy	" 12 "	Nov. 7 "
213	Prof. C. Emery	Italy	" 24 "	Oct. 30 "
214	Dr. Blochmann	Baden	Aug. 14 "	" 20 "
215	Stud. L. Hiltner	Bavaria	" 24 "	" 2 "
216	Prof. Colasanti	Italy	" 26 "	" 13 "
217	Dr. C. Chun	Saxony	Sept. 1 "	" 22 "
218	Dr. v. Lidth de Jeude	Holland	" 9 "	Dec. 1 "
219	Dr. E. Meyer	Russia	" 23 "	—
220	Dr. A. Korotneff	Russia	Nov. 6 "	April 8, 1883
221	Mr. J. T. Cunningham	British Association	" 6 "	" 24 "
222	Dr. G. Matarazzo	Italy	" 9 "	June 20 "
223	Miss E. Nunn	Cambridge	" 22 "	May 1 "
224	Dr. M. Sander	German Navy	Dec. 8 "	April 1 "
225	Dr. Ch. Julin	Belgium	" 24 "	Feb. 11 "
226	Sig. E. Stassano	Italy	Jan. 2, 1883	—
227	Dr. A. Garbini	Italy	" 7 "	June 9 "
228	Mr. A. Shipley	Cambridge	" 14 "	—
229	Sen. T. de Castellarnau	From the Spanish Government	" 15 "	Mar. 8 "
230	Prof. Geza Entz	Hungary	" 25 "	April 23 "
231	Dr. A. Gravis	Belgium	" 26 "	—
232	Cand. Th. Steeck	Switzerland	" 30 "	" 1 "
233	Dr. J. Frenzel	Prussia	Feb. 10 "	—
234	Dr. H. Masquelin	Belgium	" 11 "	Mar. 24 "
235	Dr. C. Fickert	Würtemberg	Mar. 5 "	April 16 "
236	Prof. H. Grenacher	Prussia	" 10 "	" 26 "
237	Dr. Th. Weyl	Berlin Academy	" 10 "	" 12 "
238	Prof. Graf Solms-Laubach	Prussia	" 16 "	" 5 "
239	Dr. B. Sharp	Bavaria	" 19 "	May 26 "
240	Prof. H. Fol	Switzerland	" 23 "	April 8 "
241	Mr. E. Wilson	Williams College, Mass., America	" 30 "	—
242	Dr. P. Schiementz	Prussia	April 13 "	—
243	Dr. T. Perényi	Hungary	" 23 "	June 20 "
244	Prof. C. Emery	Italy	June 15 "	—
245	Dr. T. van. Wyhe	—	" 26 "	—

III. *A List of Papers which have been published in the Year* 1882 *by the Naturalists who have occupied Tables at the Zoological Station.*

Dr. E. Jung . . De l'Action des Poisons chez les Mollusques. 'Archiv. des Scienc. phys. et nat.' 3 sér. t. 7, 1882.

Dr. W. Vigelius . Vergleichend anatomische Untersuchungen über das s.g. Pancreas der Cephalopoden. 'K. Akad. der Wissensch. zu Amsterdam,' 1882.

Dr. Th. Weyl . . Die Sänlenzahl im elektrischen Organ von Torpedo oculata. 'Centralblatt für die medicin. Wissensch.' 1882.

Prof. C. Emery . Contribuzioni all' Ittiologia. 'Mittheil. Zool. Station, Neapel,' Bd. 3, 1882.

Prof. G. v. Koch .	Ueber die Entwickelung des Kalkskelets von Asteroides calycularis. 'Mittheil. Zool. Station, Neapel,' Bd. 3, 1882.
„ „ .	Mittheilungen über das Kalkskelet der Madreporaria. 'Morphologisches Jahrbuch,' Bd. 8, 1882.
„ „ .	Vorläufige Mittheilungen über die Gorgonien, &c. Ibid.
Dr. W. Giesbrecht .	Beiträge zur Kenntniss einiger Notodelphyiden. 'Mittheil. Zool. Station, Neapel,' Bd. 3, 1882.
Prof. A. Götte .	Abhandlungen zur Entw.-Gesch. der Thiere. I. Heft. Unters. zur Entw.-Gesch. der Würmer. Leipzig, 1882.
Dr. C. de Mereschkowsky.	Eine neue Art der Blastodermbildung bei den Decapoden. 'Zoologischer Anzeiger,' 1882.
„ „	Les Suctociliés, nouveau groupe d'Infusoires, &c. 'Comptes Rendus,' 1882.
„ „	Développement des Spermatozoides dans la Méduse Cassiopea Borbonica. 'Archives Zool. éxpérim.' t. 10, 1882.
„ „	Structure et Développement des Nématophores chez les Hydroides. Ibid.
Dr. J. van Wyhe .	Ueber die Mesodermelemente und die Entwickelung der Nerven des Selachierkopfes. 'Natuurkund. Verh. Kon. Akad. Amsterdam, Deel. 22, 1882.
Dr. A. Korotneff .	Zur Kenntniss der Siphonophoren.' 'Zoologischer Anzeiger,' 1882.
Mr. A. G. Bourne .	The Central Duct of the Leech's Nephridium. 'Quart. Journ. Microscop. Science,' vol. xxi. 1882.
„ .	On Certain Methods of Cutting and Mounting Microscopical sections. Ibid.
Dr. O. Hamann .	Der Organismus der Hydroidpolypen. 'Jenaische Zeitschr. für Naturwissensch.' Bd. 15, 1882.
Prof. W. Salensky .	Beiträge zur Entw.-Gesch. der Anneliden. 'Biologisches Centralblatt,' 1882.
„ „ .	Etudes sur le Développement des Annélides. Première Partie. 'Archives de Biologie,' t. 3, 1882.
„ „ .	Neue Untersuchungen über die embryonale Entwickelung der Salpen. 'Mittheil. Zool. Station, Neapel,' Bd. 4, 1882.
Prof. H. Ludwig .	Entw.-Gesch. der Asterina gibbosa. 'Zeitschrift f. wissensch. Zoologie,' Bd. 37, 1882.
Dr. W. Uljanin .	Zur Naturgeschichte des Doliolum. 'Zoologischer Anzeiger,' 1882.
Dr. J. Kennel .	Ueber Ctenodrilus pardalis, Clap. 'Arbeiten Zoolog. Institut, Würzburg,' Bd. 5, 1882.
Dr. C. Chun .	Die Gewebe der Siphonophoren. II. 'Zoologischer Anzeiger,' 1882.
„ .	Ueber die cyclische Entwickelung und die Verwandtsch. Verh. der Siphonophoren. 'Sitz.-Ber. Berliner Akademie,' Bd. 52, 1882.
Dr. O. Whitman .	A Contribution to the Embryology, &c., of the Dicyemids. 'Mittheil. Zool. Station, Neapel', Bd. 4, 1882.
Dr. J. Carrière .	Die Fussdrüsen der Prosobranchier und das Wassergefässsystem der Lamellibranchier, &c. 'Archiv f. mikrosk. Anatomie,' Bd. 21, 1882.
Prof. E. Metchnikoff	Vergleichend embryologische Studien. III. Ueber die Gastrula einiger Metazoen. 'Zeitschr. f. wissensch. Zoologie,' Bd. 37, 1882.
Prof. A. Haddon .	Notes on the Development of Mollusca. 'Quart. Journ. Microscop. Science,' 1882.
Prof. L. v. Graff .	Monographie der Turbellarien. I. Rhabdocœlidæ. Leipzig, 1882.
Dr. G. Berthold .	Beiträge zur Morphologie und Physiologie der Meeresalgen. 'Pringsheim's Jahrbücher für wiss. Botanik,' Bd. 13, 1882.
„ .	Die Bangiaceen. Monographie (VIII.) der Fauna und Flora herausgegeben v. d. Zoolog. Station, Neapel, 1882.
Mr. W. H. Caldwell	Preliminary Note on the Structure, Development, and Affinities of Phoronis.' 'Proceed. Royal Society,' 1882.
Prof. C. Hoffmann .	Zur Ontogenie der Knochenfische, Fortsetzung. 'Verh. Kon. Akad. von Wetens,' Dl. 23, 1882.
Dr. A. Fœttinger .	Note sur la Formation du Mésoderme dans la Larve de Phoronis hippocrepia. 'Archives de Biologie,' t. 4, 1882.

IV. *A List of Naturalists to whom Specimens have been sent from the end of June* 1882 *to the end of June* 1883.

				fr. c.
1882.	June 26	Dr. Ed. Meyer, Bonn	Polyopthalmus	13·25
	„ 29	Prof. F. Roux, Lausanne	Various	70·
	„ 29	Prof. Waldeger, Strassburg	Cœlenterata	72·10
	„ 29	Dr. E. Rey, Leipzig	Various	48·85
	July 2	Società Tecnica, Florence	Various	39·20
	„ 2	Dr. L. Eger, Vienna	Spongia, Corallia	22·85
	Aug. 10	Gustav Schneider, Basel	Various	1,298·65
	„ 13	Card. Traustedt, Herlufsholm	Various	120·10
	„ 17	Dr. MacLeod, Gand	Pecten, Cœlenterata	39·30
	„ 20	Prof. Dames, Berlin	Heads of Fishes	3·25
	„ 24	L. Dreyfus, London	Various	582·75
	„ 31	Prof. Claus, Vienna	Various	346·15
	„ 31	Dr. Imhof, Zürich	Various	34·40
	Sept. 12	J. C. Puls, Gand	Vermes	168·80
	„ 15	Dr. L. Eger, Vienna	Annelides	12·
	„ 16	Società Tecnica, Florence	Various	24·10
	„ 20	Prof. W. Leche, Stockholm	Various	180·35
	„ 27	Dr. H. Griesbach, Mülhausen	Pecten, Anomia	13·
	„ 30	Prof. Ehlers, Göttingen	Various	95·
	Oct. 4	Prof. A. M. Marshall, Manchester	Various	444·95
	„ 4	Dr. Alb. Vogel, Bern	Cephalopoda	6·50
	„ 11	Prof. C. Emery, Bologna	Various	138·10
	„ 15	Prof. F. Cohn, Breslau	Alcyonium, Pennatula	8·90
	„ 23	Prof. Moseley, Oxford	Various	58·15
	„ 25	Dr. A. Vayssière, Marseilles	Tylodina	6·25
	„ 30	Rev. A. M. Norman, Durham	Various	340·20
	„ 30	Dr. L. Eger, Vienna	Sycon, Larvæ of Comatula	18·50
	„ 31	Stud. E. A. Goeldi, Jena	Balistes	8·75
	Nov. 7	Prof. Ramsay Wright, Toronto, Canada	Copepoda	18·75
	„ 9	Prof. R. Hertwig, Königsberg	Various	128·05
	„ 9	Friedrich's Collegium, Königsberg	Various	40·90
	„ 10	Zoologisches Institut, Heidelberg	Various	225·80
	„ 10	Società Tecnica, Florence	Crustacea	4·85
	„ 11	Prof. G. von Koch, Darmstadt	Alcyonium	7·50
	„ 12	Prof. P. Pavesi, Pavia	Cœlenterata, Annelides, Pycnogonida	168·40
	„ 12	Prof. Moseley, Oxford	Carinella	—
	„ 12	Prof. Sochaczever, Berlin	Chiton	4·45
	„ 15	Prof. du Plessis, Lausanne	Various	15·25
	„ 16	Prof. Traquair, Edinburgh	Various	499·80
	„ 16	Dr. Hans Virchow, Würzburg	Eyes of Fishes	31·25
	Dec. 5	Prof. J. C. Ewart, Edinburgh	All Classes	1,300·45
	„ 6	Prof. G. Mayr, Vienna	Various	56·25
	„ 10	Dr. L. Eger, Vienna	Annelidens, Medusæ	33·40
	„ 10	Prof. Stepanoff, Charkoff	Various	147·85
	„ 10	Prof. Freda, Naples	Various	107·
	„ 13	Prof. E. Howarth, Sheffield	Various	98·65
	„ 23	Prof. B. Vetter, Dresden	All Classes	1,111·30
	„ 29	Dr. Brock, Göttingen	Mollusca	15·90
	„ 29	Dr. Spengel, Bremen	Cephalopoda, Anthozoa	101·10
	„ 29	Dr. E. Rey, Leipzig	Various	139·15
	„ 31	Prof. A. M. Marshall, Manchester	Mysis, Rhyllosoma	10·60
1883.	Jan. 7	Prof. R. Kossmann, Heidelberg	Mollusca	24·35
	„ 7	Prof. A. Weismann, Freiburg	Obelia	7·75
	„ 19	J. R. Bradford, London	Various	68·30
	„ 24	Prof. Emery, Bologna	Pterotrachea	7·75
	„ 28	Prof. A. Haddon, Dublin	Various	407·05
	„ 28	„ „	Chiton, Patella, Fissurella	18·
	„ 28	Prof. C. Vogt, Geneva	Bonellia	23·75
	„ 31	Dr. Aug. Müller, Frankfurt a. M.	Elementary collection	265·50

					fr. c.
1883.	Jan. 31	Società Tecnica, Florence	.	Various	22·25
	„ 31	Dr. A. Batelli, Arezzo	.	Various	13·45
	Feb. 6	Madame Vimont, Paris	.	Various	77·5
	„ 6	Prof. Salensky, Odessa	.	Salpa	7·75
	„ 9	Dr. Orley, Budapest	.	Various	611·45
	„ 15	Prof. Moseley, Oxford	.	Various	115·85
	„ 15	Prof. R. Moniez, Lille	.	Various	262·35
	„ 26	Conte de Begouen, Toulouse	.	Various	20·
	„ 28	Dr. P. C. Hoeck, Leyden	.	Cirripedia	21·40
	March 13	Joseph Rinnböck, Vienna	.	Various	105·15
	„ 16	Queen's College, Cork	.	Various	448·20
	„ 16	Madame Vimont, Paris	.	Various	500·45
	„ 16	E. E. Howel, Rochester	.	Terebratula	4·
	„ 17	Dr. L. Eger, Vienna	.	Calliactis	17·50
	„ 18	Società Tecnica, Florence	.	Various	37·45
	„ 22	Zoologisches Institut, Würzburg		Scalpellum	4·75
	„ 30	Dr. Steck, Bern	.	Various	61·90
	April 2	Domenico Candida, Naples	.	Various	6·10
	„ 3	Zoolog. Institut, Heidelberg	.	Mollusca	42·50
	„ 3	Prof. Gibelli, Bologna	.	Algæ	5·90
	„ 3	Anat. Dept., University, Camb.		Lacerta, Julus	11·
	„ 17	Anat. Dept., University, Camb.		Various	53·75
	„ 18	Prof. C. Emery, Bologna	.	Reptilia	11·75
	„ 18	Dr. van Bemmelen, Utrecht	.	Chiton	6·
	„ 23	L. Dreyfus, Wiesbaden	.	Various	580·65
	„ 23	Dr. Virchow, Würzburg	.	Electrical Organs of Torpedo	7·75
	„ 26	Fisheries Exhibition, London	.	All classes	6,000·
	„ 26	Dr. W. J. Vigelius, Dordrecht	.	Mollusca, Pisces	84·25
	„ 26	Herr van Emden, Dordrecht	.	Cephalopoda	20·
	May 5	Prof. H. Fol, Geneva	.	Various	98·50
	„ 5	Prof. Moseley, Oxford	.	Squilla, Radiolaria	54·
	„ 5	Prof. Grenacher, Halle a. S.	.	Various	994·70
	„ 8	Signora Marg. Boll, Rome	.	Palæmonetes	12·
	„ 9	Società Tecnica, Florence	.	Various	213·
	„ 9	Prof. W. Leche, Stockholm	.	Vermes, Bryozoa	44·15
	„ 14	Prof. Friant, Nancy	.	Various	331·75
	„ 22	Madame Vimont, Paris	.	Various	1,091·5
	„ 22	H. Joos, Roehlitz	.	Various	61·
	June 8	Dr. Otto Hamann, Göttingen	.	Synapta	7·75
	„ 25	Prof. G. von Koch, Darmstadt	.	Various	23·
	„ 30	Dr. L. Eger, Vienna	.	Various	170·85
					21,565·85

V. *A List of Naturalists to whom Microscopic Preparations have been sent from the end of June* 1882 *to the end of June* 1883.

					fr. c.
1882.	June 29	Prof. F. Roux, Lausanne	5	preparations	10·
	„ 29	Prof. W. Leche, Stockholm	13	„	22·
	„ 29	C. Baker, London	46	„	73·35
	Sept. 19	Prof. W. Leche, Stockholm	19	„	40·
	„ 19	Prof. Haddon, Dublin	44	„	101·
	Oct. 7	University of Wisconsin, Madison	26	„	60·
	Nov. 9	L. Dreyfus, London	27	„	38·
	„ 9	Prof. Ramsay Wright, Toronto	96	„	181·25
	„ 9	Prof. Gasco, Rome	106	„	194·50
	Dec. 2	Dr. Gustav Mayr, Vienna	7	„	8·
1883.	Feb. 1	Prof. F. Jeffrey Bell, London	19	„	29·
	March 5	Prof. Ewart, Edinburgh	102	„	197·50
	„ 5	Prof. W. Salensky, Odessa	55	„	109·
	April 3	Professor Grenacher, Zool. Mus., Halle	84	„	150·
	May 10	Prof. W. Leche, Stockholm	2	„	2·
					1,215·60

Report of the Committee, consisting of Dr. PYE-SMITH, Professor DE CHAUMONT, Dr. M. FOSTER, *and* Dr. BURDON SANDERSON (*Secretary*), *reappointed for the purpose of investigating the Influence of Bodily Exercise on the Elimination of Nitrogen* (*the experiments conducted by* Mr. NORTH). *Drawn up by* Mr. NORTH.

IN my last Report I stated that the work machine, for which I was granted 50*l.* at the York meeting, had just been delivered by the makers, and expressed a hope that in my next report I might be able to give the results of experiments with it. I regret that unforeseen circumstances have prevented me from making trial of it in experiments upon the elimination of nitrogen, but that the whole of the past year has been spent in remedying defects, and materially altering the machine in many ways.

The principle on which the machine was constructed seems in every respect to be satisfactory, but several very serious difficulties have had to be overcome before it could in any sense be said to be complete and ready for work.

Firstly, the original arrangement for supporting the body during the progress of the work was found to be unsuited to its purpose, and another arrangement was, after many trials, adopted. This appears to be satisfactory, and to give such a power of adjusting the position of the body with regard to the work as is required.

Secondly, the buffer on to which the weight fell was found to require modification, the chief reason being the great noise which the sudden stoppage of the weight caused. After considering carefully various forms of buffer—air, hydraulic, and spring—I finally adopted the simple expedient of an iron anvil weighing 140 pounds, covered at the top with two inches of rubber. This serves two purposes—firstly, to deaden the sound, which it does to a very considerable extent; and secondly, to give stability to the part of the machine in which it is placed.

Thirdly, it was found necessary to raise the cam and pulley on an iron box, there not being otherwise sufficient room for the play of the weight.

Fourthly, to strengthen and support the self-releasing gear by means of gun-metal guides. This was a most important improvement, and greatly added to the efficiency of the machine.

Fifthly, to substitute a wire rope for the hemp one originally used, which broke at every trial, and when a heavier one was tried was found to stretch so much as to render the releasing gear useless, and ultimately to break. The use of a wire rope necessitated the use of specially constructed 'strainers' for adjusting it. After several apparently very satisfactory trials one of these broke, and from the great strain upon it the recoil of the rope was nearly the cause of what might have been a very serious accident. A new one was constructed and fresh trials were made, with the result that the rope broke again two or three times, without any very apparent reason. I ultimately discovered that the momentum imparted to the heavy cam by the sudden descent of the weight, caused a very great and very sudden strain to be put upon the rope in one

particular place, and that this was aggravated by its being at the same time and by the same means brought into very violent contact with the sharp edge of the pulley. This, after several operations, resulted in the rope being seriously damaged and so weakened that the next trial broke it. This difficulty has been remedied by the introduction of a sort of self-acting brake, so that I hope the mechanical difficulties are now overcome.

In conclusion, whilst expressing my thanks for the assistance which has been afforded me in procuring what I believe to be a very necessary machine for investigations on the external work of the body, I ask that my Committee may be reappointed, without further grant of money, for the ensuing year.

Report of the Committee, consisting of Mr. R. MELDOLA, General PITT-RIVERS, Mr. WORTHINGTON SMITH, *and* Mr. WILLIAM COLE, *appointed to investigate the Ancient Earthwork in Epping Forest, known as the 'Loughton' or 'Cowper's' Camp.*

[PLATES II. AND III.]

IN ancient times an immense forest probably covered the greater part of the county of Essex, and, as a remnant of this vast tract of woodland, the present Epping or Waltham Forest possesses very considerable interest to the naturalist and antiquary. Although in the progress of agriculture the county generally has become highly cultivated, the stringency of the old forest laws, and the various rights of cattle-feeding and wood-cutting in more recent times, have effectually combined to check enclosures and clearing, and to preserve to Epping Forest many of the characteristics of a primitive woodland. The soil in most of the woods has remained undisturbed within historic times, except in a few spots where local gravel-pits have been opened. It is not surprising, therefore, that relics of former conditions of life should still exist in the forest, undefaced except through the action of natural agencies; but until very recently the district has not received from archæologists the attention it deserves, and it is more than probable that further traces of prehistoric occupation will yet reward the persevering explorer. At the present time the forest is known to contain two ancient earthworks or camps, which are of more than ordinary interest, being perhaps the best preserved examples of such structures in the immediate neighbourhood of London. One, locally called 'Ambresbury,' 'Amesbury,' or 'Ambers' Banks, is situated in the forest about 1½ miles south-west of the town or village of Epping Street, and about a hundred yards to the right of the road to Epping, which was made early in the sixteenth century. This position rendering it easy of discovery, the Ambresbury Camp has long been known, and the meagre and unsatisfactory details usually given of such remains are to be read in the local histories. In 1881 the Essex Field Club carried on some explorations at Ambresbury Banks, a report upon which, drawn up by General Pitt-Rivers, was read at the York Meeting of the British Association,[1] and published *in extenso* in the 'Transactions' of the Club

[1] *Brit. Assoc. Report*, 1881, p. 697.

(vol. ii. p. 55), with plans of the camp constructed by Mr. D'Oyley, and coloured figures of the objects found. These relics, consisting of small fragments of very rude pottery and a few flint 'flakes,' determined the camp, in the opinion of General Pitt-Rivers, to be of British or Romano-British construction, but the data obtained were insufficient to fix the age of the entrenchment with greater precision.

The second entrenchment, now called the 'Loughton' or 'Cowper's' Camp, remained unknown until it was discovered by the acumen and perseverance of Mr. B. H. Cowper. Mr. Cowper thus recounts the circumstances attending his recognition of the camp:—'In the course of my researches in the forest, I came, in the summer of 1872, into the neighbourhood of Loughton. There it was that I suddenly detected what appeared to be a portion of a moated enclosure. A short investigation was then all that I could make, but I was convinced of the reality of the conjecture. I made some inquiries, but failed to discover any record or local knowledge of a camp in that portion of the forest, and there the matter ended for the time. In 1875 I returned, and after several efforts managed to complete the circuit of the camp, which was a difficult operation. I gave as much publicity as possible to the discovery, and in addition went over all the ground between the Loughton Camp and Ambresbury Banks. Friends took an interest in the matter, and foremost among them was Mr. W. D'Oyley, who rendered the greatest service and accomplished a complete survey of both the ancient earthworks.' By means of this discovery Mr. Cowper rendered an important service to the knowledge of the archæology of the forest district, and in his various papers on the subject, the titles of which are here recorded, he gave a careful description of the earthwork and its surroundings, and compared it with the neighbouring Ambresbury Banks. Mr. Cowper's writings on the subject are as follows: (1) 'Notes on an Entrenched Camp in Epping Forest, with plan by Mr. D'Oyley;' read at a meeting of the Royal Archæological Institute, November 5, 1875;[1] (2) 'Ancient Earthworks in Epping Forest;'[2] (3) 'Ancient Camps in Epping Forest, with plans by William D'Oyley, of Loughton,' a pamphlet published by the Committee of the 'Epping Forest Fund' in 1876, and now rare; (4) 'Epping Forest and its Ancient Camps,' (with woodcut).[3] We gladly acknowledge our indebtedness to these papers for many details. Mr. D'Oyley's labours in the delineation of the two camps call also for grateful recognition, inasmuch as they materially aided the explorations which were afterwards undertaken.

The Loughton Camp is situated about a mile north of the village from whence it takes its name, and about two miles south-west of Ambresbury Banks. It is placed in the depths of the forest, the trees surrounding and covering it being principally beech and oak; some very ancient specimens of the former tree actually grow upon the ramparts, and many old hollies are to be found both within and around the entrenchments. Its circumference is about 800 yards, giving a contents of between 11 and 12 acres; the two known forest camps being very nearly of a size. The construction of the camp is also very similar to that of the Ambresbury entrenchment, an outer broad ditch having been dug, and the earth so obtained thrown up on the inside to form a rampart.

[1] *Archæological Journal*, vol. xxxiii. p. 88. [2] *Loc. cit.* p. 245.
[3] *Cassell's Family Magazine*, vol. iii. (1877), p. 153.

In the report on the Ambresbury Banks allusion was made to the somewhat irregular lines of the fortification as contrasted with those of camps of known Roman origin. In the Loughton Camp strict symmetry of proportion has been completely disregarded by its constructors, and there are scarcely any defined angles (see Plate II.). The form of the camp is that of an imperfect oval, and the lines of the rampart appear to follow and to have been controlled by the natural contours of the ground. It has suffered to a much greater degree than Ambresbury Banks from the effects of age and denudation. In many places the burrowings of foxes and rabbits have caused much damage, increased possibly, in some instances, by foresters in digging out the animals, or even in removing sand in very modern times. In one place in particular, on the western side, the bank and trench have nearly disappeared, the soil having apparently literally tumbled down the slope of the valley, a result probably due to natural agencies, this being a very exposed part of the fortification. We are sorry to report that in the course of the construction of a recently designed 'Green Ride' through the forest, a considerable portion of the western glacis has been cut away, and the original appearance of the rampart at that spot completely destroyed.

The position of the camp is remarkable; and, considered from a military point of view, it is perhaps the most advantageous in the whole forest district. It occupies the southern headland of an elevated plateau, many parts of which are densely wooded. From the southern side of the camp an extensive view may be had looking towards the south-east, bounded by the Kentish hills beyond the Thames. The Lea Valley to the west is shut out by the long ridge forming High Beech, which is higher than the ground occupied by the camp. At the northern angle of the camp the elevation is about 310 feet above the Ordnance datum. The ground gradually trends away towards the southern rampart, and then suddenly dips down to Debden Slade, a low marshy valley distant about 1,000 feet to the south (Plate II.), the level of which is only 160 feet above datum, showing a fall of about 120 feet from the southern aspect of the camp, or 150 feet from the higher plateau-ground at the northern end. From the western side the ground descends even more abruptly, to form a smaller valley, the levels showing a fall of about 70 feet. This valley falls to the south to join Debden Slade. From the north-west corner of the camp the higher ground forms a headland to this valley, and is continued for a distance equal to about half the length of the camp into a spur towards the south. This tongue of land, being some 10 feet higher than the western rampart, and running almost parallel with it, may possibly have been originally included in the plan of the fortification; but any evidences of entrenchment have probably suffered so much from recent gravel diggings, that no safe conclusions can be drawn therefrom. Mr. Cowper, however, thought he could trace a lower trenching round the head of the valley, continuing for some distance along the crest of the spur.

The high plateau-ground from which this spur springs is continued round the northern and north-eastern corners of the camp. The ground then descends by the eastern side into a swamp at the south-east corner, and eventually trends away into the deep valley, Debden Slade, before mentioned, the rampart itself sweeping with a gentle curve until its outlines are lost in the slopes of the morass.

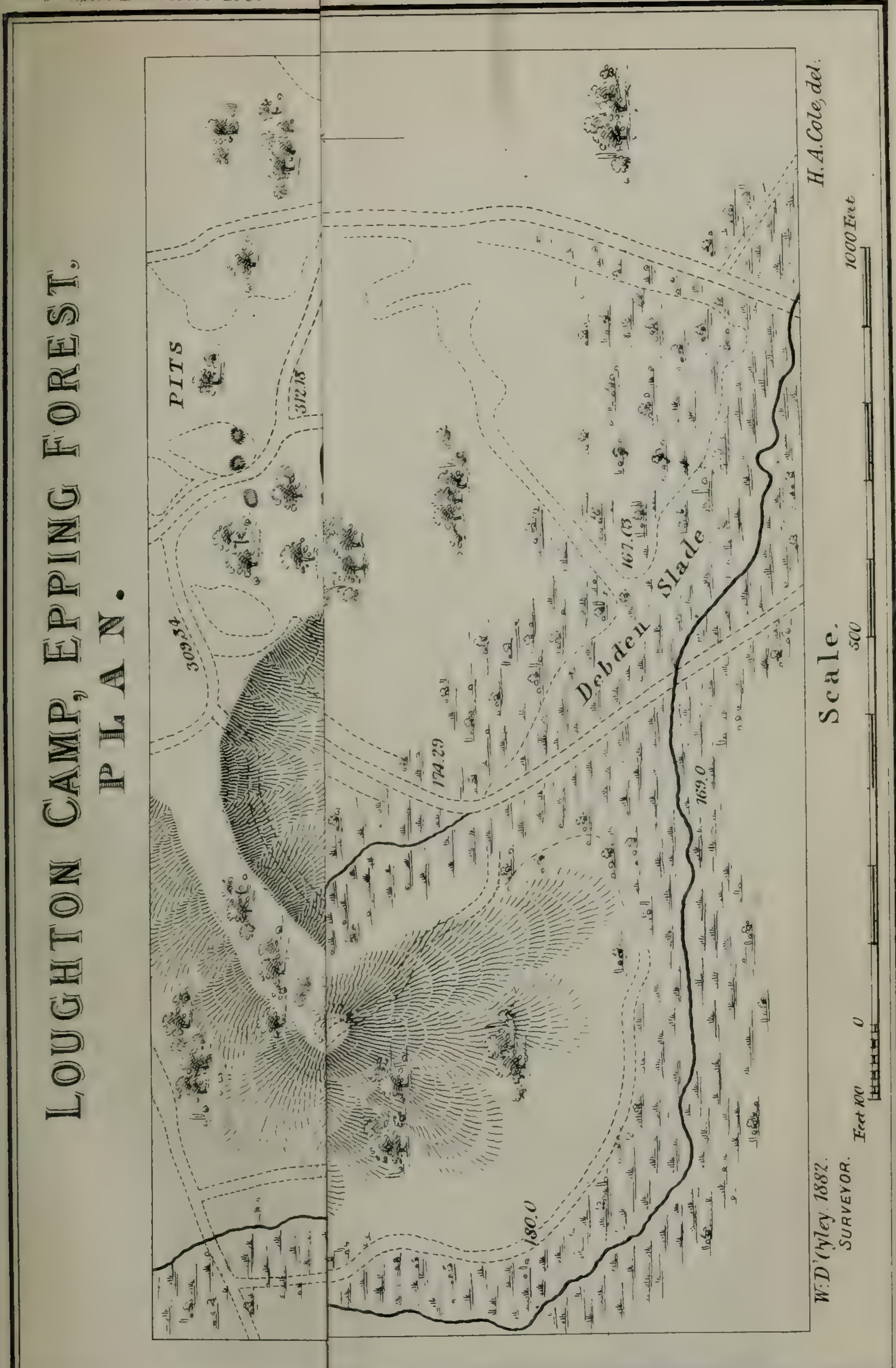
This little 'morass' (which is a piece of true bog-land, containing

Sphagnum, *Hypericum elodes*, and other marsh-loving plants) occupies a small valley, which leads up into the interior of the camp. At the spot where the bog seems to originate is a small circular *pit*, which has every appearance of being a water-well of artificial construction. At present, however, we have no direct evidence to connect this well with the original makers of the camp. It is now choked with leaves, &c., but it still appears to supply water to feed the bog, the quantity being largely augmented in winter and spring by the surface drainage from the higher ground at the northern part of the camp. The ridge of ground on which the rampart runs somewhat contracts the limits of the bog at the north-west corner of the camp, and a little outside the line of entrenchments a bank can easily be recognised running across the morass, leaving a narrow 'gate' or floodway towards the east. This bank is perhaps the remnant of an ancient *dam*, by which a head of water could have been retained in the interior of the camp for the use of the inhabitants, a constant supply being furnished by the artificial 'well' before noticed. These statements must be put forward somewhat hypothetically; no cutting has yet been made through the 'dam,' nor has the 'well' been explored, and consequently the evidence is wanting which would conclusively prove these structures to be coeval with the camp itself. But they are, nevertheless, very interesting, and cannot be passed over in any description of the place.

Two well-defined, and perhaps old, entrances exist at the northern end of the camp, through one of which a 'driftway' runs—a very hard and good path, which leaves the camp by an outlet at the southern slope to descend to Debden Slade, and so to Loughton. A good and old path, branching out from the first, runs outside the northern and eastern ramparts also to Loughton. The three inlets to the camp appear to be ancient, but at present we have no means of fixing their age relatively to the ramparts.

Several *pits* of varying size exist in the camp, and they are numerous on the high-level ground, stretching from the head of the little valley on the west round the northern aspect of the ramparts. It is possible that some of these pits may owe their origin to the exertions of sand-seekers; but many of them must be of considerable antiquity, as they are densely overgrown with trees, and we are disposed to think that these at least may have been constructed by the occupiers of the camp, and have had some connection with their habits of life. The regular circular form of some of these pits, and the distance of the site of the camp from any high road (for the present Epping New Road is, of course, very modern), by which vehicles could reach this densely-wooded district, are circumstances sufficient to throw grave doubt upon the suggestion that they were made by gravel-diggers. A cutting was made in one of the pits within the camp; and in the silt, about 2 feet down, an artificial black flint flake, perfectly unweathered, was found (No. 38). It is hoped that some further examination of these pits may be made, pending which any hypotheses as to their age or probable uses must necessarily be little more than guesswork.

Mr. Cowper has called attention to some banks on the ground between the Ambresbury and Loughton Camps, and similar works have recently been detected on the high ridge by the 'King's Oak,' to the west of the Loughton Camp. Owing to the denseness of the forest, an accurate survey of these banks would be somewhat difficult, and it has



LOUGHTON CAMP, EPPING FOREST,
PLAN.

orest.

Spottiswoode & Co. ... London.

Illustrating the Report on the Ancient Earthwork in Epping Forest

not yet been attempted. We are, therefore, not in a position to describe them more definitely, but they are certainly artificial, and would seem to deserve a thorough examination. Mr. D'Oyley also directed our attention to a somewhat remarkable configuration of the ground at one spot in the deep valley to the south-east of the camp. The footpath leading thither from the camp is, at almost its lowest point, flanked by several very 'mound-like' ridges of soil, densely covered with vegetation. A section was cut through one of these, but no signs of artificial construction were discoverable. It is probable that they are purely natural formations, caused by the erosive action of the surface water flowing down rapidly from the higher ground which the camp occupies in sufficient quantity and force to wear away the lighter soil, and so leave these ridges of denser clay standing boldly out above the general level.

The above sketch comprises the information at present in our possession concerning the external features and natural surroundings of the Loughton Camp, and we now proceed to detail the results of the diggings into the ramparts. The investigations were carried on under the auspices of the Essex Field Club by a sub-committee of that society including all the members of the present committee, the necessary funds being subscribed by members of the club, supplemented by a grant of 10*l.* from the Council of the British Association. Permission having been granted by the Epping Forest Committee of the Corporation of London, the work was commenced on May 29, 1882, and continued until June 14, the removal of the earth being very carefully watched by members of the joint committee, under the direction of the hon. secretary, Mr. W. Cole, Mr. W. D'Oyley also kindly giving his services as surveyor. The mode of working both in theory and practice was so fully explained by General Pitt-Rivers in his report upon Ambresbury Banks,[1] that it is unnecessary to repeat the details here. Sections were cut through the rampart and ditch so as to expose the 'old surface line,' or the original floor of earth upon which the soil dug out in making the fosse was heaped by the constructors of the camp to raise up the ramparts. The earth being generally of a more sandy nature than at Ambresbury Banks the sieve could be freely used, and each spadeful was sifted on its removal and carefully examined for relics, the position of each object found being registered on working drawings of the cuttings. The contract for the work was taken by Mr. Cuthbert, of Loughton, and a word of praise is due to our four workmen, who displayed great care and intelligence in the somewhat tedious and delicate tasks set before them.

The position of the cuttings is shown on the plan of the camp. The first was 12 feet in width, and it was carried from the foot of the silting of the interior slope on for 80 feet through the rampart and ditch to the counterscarp. The camp at this part has suffered severely from denudation, owing to the light nature of the soil. As will be seen by an inspection of the plan of the cutting (Plate III.), the present height of the rampart is only about 5 feet 6 inches above the 'old surface line,' and the ditch is filled up with silt to the depth of about 6 feet. In this first section the silting was so similar in appearance to the undisturbed earth, that the outline of the fosse could not be followed out with any certainty, and even the escarp was very difficult to trace.

The following is a catalogue of the objects found in the first cutting,

[1] *Transactions Essex Field Club*, ii. p. 55, and *Proc.* ii. xxviii.

the position of each being carefully indicated by numbers on the plan (Plate III., fig. 1). The horizontal measurements were taken from a post driven into the ground at the point where the silting of the interior slope seemed to end (marked 'O' in section), and the vertical positions from the present surface of the rampart; everything being, of course, projected on one vertical plane:—

No. 1. A small black characteristic flint flake, with good 'bulb of percussion' and three 'facets.' Found beneath the silt at the foot of interior slope, with charcoal and burnt stones, a considerable quantity of which were turned up by the spades from the 'old-surface line' spit for about 20 feet from the commencement of the cutting. Near a deposit of charcoal three flint flakes (No. 2) and two 'cores' from which flakes had been struck ('H') were found.

Nos. 3, 5, and 6. Five small fragments of pottery of very irregular shape, the largest about 2 inches by 1·5 inches and about 0·5 inch thick. They are dull red in colour, somewhat darker on the smoother or interior surface, and quite blackish in the middle of the paste, owing to imperfect firing. The texture is very coarse, the pottery containing angular pieces of quartz and coloured pebble of comparatively considerable size, with sand. It is decidedly hand-made, and probably of British manufacture. Found on or near old surface line, beneath the crest of the rampart, 30–35 feet from foot of interior slope, with abundant traces of charcoal, &c.

No. 4. Black flint flake, not weathered, with good 'bulb' and two 'facets.' Found with Nos. 3, 5, and 6.

No. 7. 'Outside' flint flake near old surface line, beneath crest of rampart.

No. 8 (*a*, *b*). Two good flint flakes, unweathered; the narrower one (*b*) showing distinct marks of use at both ends. Found beneath exterior slope of rampart, about 2½ feet down.

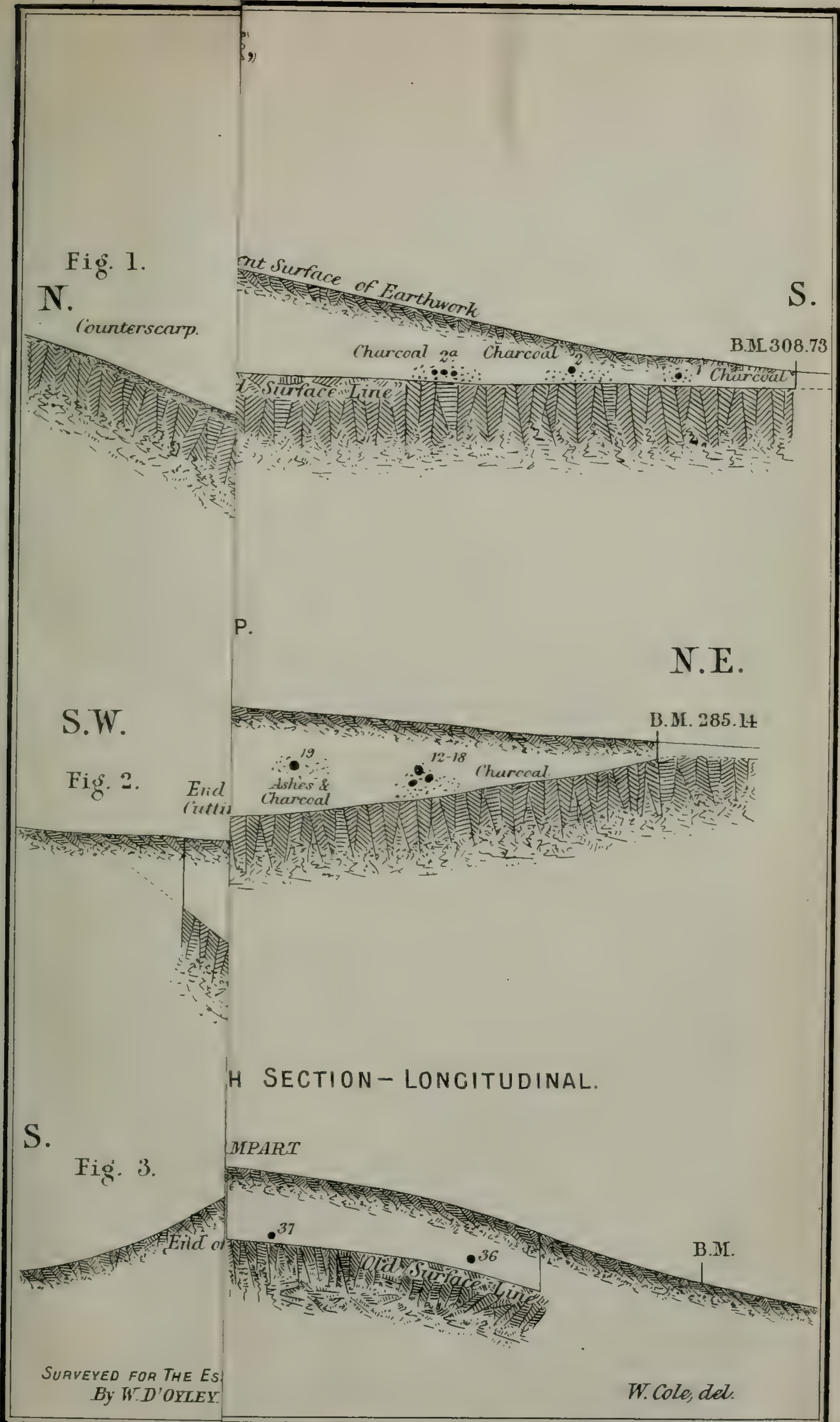
Nos. 9 and 10. Flint 'core' and flake with many 'facets,' both unweathered; found in exterior slope of rampart, about 2 feet down.

No. 11. Flint 'core,' from which flakes have been struck; found about 3½ feet down in the silt accumulated in the fosse.

The indistinctness of the outlines of the ditch, and the paucity of the evidence above obtained, rendered another cutting necessary, and a new one, seven feet wide, was commenced on June 8 through the vallum near the south-west corner of the camp. The line of junction between the made earth, silt, and the original surface, was here more clearly traceable, and could be laid down with tolerable accuracy upon the plan, except the commencement of the escarp, concerning the exact angle of which some little doubt was felt. On clearing out the fosse, in which 6½ feet of silt had accumulated, its form was found to be pointed, as was the case at Ambresbury. The soil at the bottom of the ditch was quite peaty, and water rose in the cutting for a foot or two. The rampart is now only about six feet above the old level of the earth, and its angles are so altered by severe 'weathering' that its original form is not recoverable. In this second section (Plate III., fig. 2) the following objects were found:—

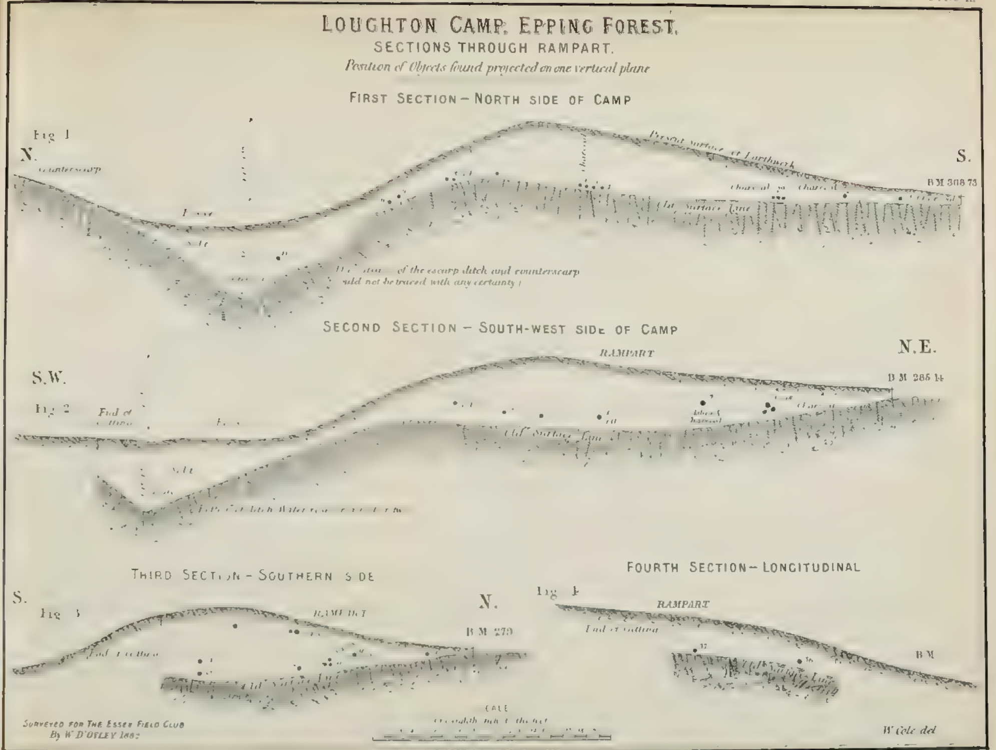
Nos. 12, 13, and 14. Three good pointed flakes, showing good 'bulbs' and several 'facets,' two of greyish, and one of reddish coloured flint, unweathered. Found with the following:—

Nos. 15, 16, and 18. About two dozen flint flakes, with bulbs of percussion, and some exhibiting one or more 'facets,' all quite unweathered;



Forest.

Spottiswoode & Co. Lith London



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found with Nos. 12 and 13, and other flakes and chips, large quantities of charcoal, burnt stones, &c., near foot of interior slope of rampart, about two feet from surface. There were evident signs of a large fire at this spot, around which the flakes were scattered.

No. 19. Good black flint flake, unweathered; found further in the rampart than the last, but also near abundant traces of charcoal, burnt stones and ashes.

No. 20. Flint celt, somewhat roughly chipped; about 5 inches long, and 1·5 inches broad, with worked chisel-like ends, and one side chipped into an acute edge, the other being obtuse. Perhaps not finished, but unweathered. Found well beneath the body of the rampart, about 4 feet down (see *infra*, p. 250).

Nos. 21, 22, and 23. Five flint flakes, with 'bulbs' and two or more 'facets,' found well under the crest of the rampart, and considerably above the old surface line.

No pottery was found in the second section, although every possible care was taken that even the smallest fragments should not be passed over. General Pitt-Rivers examined the ground and the objects obtained, but he and the other members of the Committee were of opinion that further evidence should be sought for before any safe conclusion could be arrived at as to the period of the camp. A third cutting was therefore commenced on August 14, the spot selected being a good piece of rampart near the south-east corner of the camp. This cutting was 8 feet wide, but as the escarp was thickly covered with large trees, and the form of the ditch had been determined in the second section, it was not considered necessary to incur the expense of carrying the trench beyond the crest of the rampart, about 26 feet from the base of the interior slope. The old surface of the earth was readily recognised, and was found to take a deep downward slope, so that the 'made earth' of the rampart, although externally apparently greatly denuded, was at least 6 feet thick at the deepest part. The following objects were found in this cutting (Plate III., fig. 3) :—

Nos. 24 and 35. Flint 'core,' artificial splinter, and flake. Found in interior slope of rampart, about 15 feet from commencement of cutting, and about 2 feet from the surface.

No. 25. Flint 'core,' found in crest of rampart, about 18 inches from the surface.

Nos. 27 to 32. Twelve pieces of pottery, varying in size from 2·5 inches by 1·5 inches to quite small fragments, all being about 0·3 inch thick. This pottery is of superior quality to that found in No. 1 cutting. It is thinner, harder, and is formed of a sandy clay with no grains of quartz or pebbles in the paste. The colour is dull reddish-brown on the surface, but a blackish tint obtains in the centre, the result of imperfect firing. The curved form of most of the fragments shows that they belonged to circular vessels, and two of the pieces have 'rims,' somewhat rudely modelled, which project about 0·1 inch. There are no signs of lathe turning, and the pottery was doubtless handmade. A black flint flake was found near No. 30. All the pieces came from well within the interior slope, about 2½ feet from the surface of the rampart.

No. 33. Two flakes, one with three or four 'facets;' and No. 34, a long slender flake, having good 'bulb' and many facets; all unweathered, and from well under the crest of the rampart.

A fourth cutting was made longitudinally into the same piece of rampart, at the point where it slopes away into the morass, at the south-

east corner, above described. This trench was 6 feet broad, and about 14 feet long (see Plate III., fig. 4); in it were only found—

No. 36. A small fragment of pottery, seemingly a portion of the base of a rudely-made vessel, in quality not distinguishable from Nos. 27–32. Near old surface, about 2 feet from surface of rampart. A small flint flake was found with it, and another (No. 37) further up the cutting, both unweathered.

The number of flint flakes in the rampart of this camp is somewhat large in proportion to the amount of material excavated. Many flakes of a ruder class than those catalogued, artificial splinters of flint, and rude 'cores,' have not been kept.

The flakes are all as sharp as on the day they were struck off, only one showing signs of use (No. 8 *b*); they all have the 'cone of percussion,' are lustrous, and the flints from which they were made belonged to the local gravel deposits. Several exhibit small ferruginous concretions upon them.

The discovery of a large number of flakes, and a quantity of burnt wood and burnt stones in one position in the second cutting (*vide* Nos. 16–18) seems to point (as was first suggested by Mr. H. A. Cole who was watching the excavations at the time) to the presence of a camp fire at that spot, round which fire the occupiers sat and made their weapons and tools of flint. This idea was confirmed by the fact of several flakes having been manifestly struck off from the same block of flint. After a hasty examination of the flakes from this position, Mr. Worthington Smith speedily replaced one flake on to a second somewhat larger one from which it had been originally struck: when replaced, a flat basal end belonging to the core was indicated by the truncated ends of the two flakes.

Among the flakes was a rude but cleverly chipped flint chisel or celt (No. 20), not polished in any part, but exhibiting traces of the original 'crust' or 'bark' of the flint in one or two positions. This instrument is of somewhat remarkable form, one side edge being acute, and the other flat, and some doubt exists as to whether it was really intentionally chipped into its present shape, or whether it is simply unfinished on one side. Mr. Smith remarks, 'If this instrument is really a chisel meant to be held unmounted in the hand, and the broad end designed for use, the obtuse end makes it convenient for handling, as the thumb of the right hand naturally rests on that edge.'

No other implements were found in the excavations, and this is not remarkable, as unless they were found in the bottom of the ditch they were hardly likely to be found in the rampart; they could only get there by accident during its erection.

The number, position, and unweathered condition of the flakes seems to indicate that they were struck off at the time the camp was made, and that the makers of the structure used flint tools, but we put forward this suggestion with diffidence, as great caution is necessary in making deductions from the evidence at present in our possession, and we beg leave to refer to General Pitt-Rivers' separate opinion on this point given herewith.

Flakes, of course, are the waste splinters of flint struck off in the manufacture of tools, and were esteemed only as rubbish by the tool-makers. The question now is—Where are the finished tools which were produced by the flaking? Judging from what we know of other camps, and from

the fact that a body of men, who perhaps used stone weapons and tools, probably lived inside the camp, it is not unreasonable to suppose that finished tools may be found within the space enclosed by the ramparts, if the original floor be exposed by the removal of a foot or two of the humus by which it is now covered. In this position celts, arrow-heads, 'scrapers,' 'knives,' 'fabricators,' and other tools might be found, as we find them in the soil of other camps when the interior is disturbed by the plough.

Although none of the specimens appear to precisely agree in quality and texture with those found in Ambresbury Banks, still, as in that earthwork, the pottery of the Loughton Camp may be divided into two classes. The first is of a very coarse manufacture, the clay containing fragments of quartz and pebble; the other is thinner, of finer material, harder and closer in texture, and without the angular stony grains. Both classes are manifestly insufficiently fired, and all the specimens are *hand-made.* They have been submitted to Mr. A. W. Franks, F.R.S., of the British Museum, who points out the great difficulty of accurately estimating the age of rude pottery where no ornamentation is present to afford a clue, and where only small fragments are available for determination. He is, however, disposed to rank the potsherds found as of *late Celtic* age and manufacture. The pottery and flints have also been carefully examined by General Pitt-Rivers, who has written a report upon them, which we give in his own words:—

'I regret much that the pressure of other business has prevented me, excepting on one occasion, from being present at the excavations of the Loughton Camp; but I have examined the specimens found in the cuttings, and very carefully preserved and ticketed by Mr. Cole.

'The pottery found in the first section on the old surface line, and in the body of the rampart, is of the coarse kind, with some large grains of some foreign material intermixed, which is commonly found in the ramparts of British camps. The pottery of the third and fourth cuttings is of a superior quality, without large grains, and apparently better baked; but the vessels had small irregular rims, and there is, I think, sufficient evidence upon them to show that they were hand-made, and not lathe-turned. Pottery of these two qualities not unfrequently occur together in British camps. There is no ornamentation to positively identify any of the fragments as *late Celtic*; but, judging from the results of other excavations, I see no reason why they should not be of that period. I should certainly consider them pre-Roman.

'With respect to the flint flakes found in the body of the rampart and on the "old-surface line," I do not consider the presence of flakes in these positions to afford positive proof that they were in use at the time of the construction of the camp. There are many spots on the surface of hills in which, if a rampart were to be thrown up *now* and explored at some future time, both the old surface line and the body of the rampart would be found to contain numerous flakes, the remains of earlier occupation by prehistoric man. I have also quite recently found the old surface line of a rampart thickly strewed with flakes, while other cuttings in the *same rampart* have shown evidence that the camp was of a more recent date than that in which flint tools were used. The comparative freshness of the flakes, however, although it may to some extent be attributed to the sandy nature of the soil, appears to me to favour the opinion that they were struck off and covered up soon after; and the finding of several fragments fitting one another confirms this view, as noticed by

Mr. Worthington Smith. The discovery of a half-formed flint celt also appears to me to corroborate this opinion.

'On the whole, therefore, judging from the specimens Mr. Cole has been good enough to show me, I think the evidence is sufficient to identify the camp as pre-Roman, and probably of very early period.'

In conclusion, we may be permitted to point out that the whole evidence brought forward in this report agrees well with the theory of a British origin of the camp. Its irregular outlines, and the way in which the ramparts were adapted to the form of the hill on which it is placed, are characteristics of British methods of castrametation. The V-shaped section of the fosse is, as was pointed out by General Pitt-Rivers in his Report on the Ambresbury Banks, a very noteworthy feature, and an exceptional one, in British camps, so far as our knowledge extends; the ditches in the camps at Cissbury, Caburn, and Seaford were all flat-bottomed. The worn appearance of Loughton Camp, and the immense amount of denudation apparent in many places, favours the idea that it may be of earlier date than Ambresbury Banks, although both are of British workmanship. Whether their constructors used flint tools in ordinary life can only be satisfactorily determined by means of further explorations, both in the ramparts and within the enclosures. The numerous pits in the Loughton Camp, and the ground around the supposed 'well,' also deserve attention. The extended examination of these earthworks and the other prehistoric remains in the forest is a matter not only of scientific importance, but also of very considerable popular interest to all inhabitants of London and its environs, who have now, thanks to the Corporation, a sort of personal lien upon its many attractions. No better or more permanently useful work can engage the energies of local scientific societies than an endeavour to gain and place on record some definite and accurate information respecting such prehistoric antiquities as may still exist in their neighbourhoods; and we hope that the Essex Field Club may soon be placed in a position to continue the inquiry on the lines pointed out, which have already given such interesting results.

The Committee has great pleasure in thanking the Corporation of London for permission to explore the camp, and Mr. D'Oyley, the hon. surveyor to the Essex Field Club, Mr. R. L. Barnes, Mr. W. H. Bird, Mr. A. W. Franks, Captain McKenzie, Mr. J. Spiller, Mr. C. Thomas, and Keeper Pearce, and others, for kind aid afforded during the progress of the work.

Description of Plates.

PLATE II.

Plan of Loughton Camp, showing the position of the excavations, and part of surrounding country.

PLATE III.

Figs. 1–4. Diagrams of the sections through the rampart.

Final Report of the Anthropometric Committee, consisting in 1882–3 *of* Mr. F. GALTON (*Chairman*), Dr. BEDDOE, Mr. BRABROOK (*Secretary*), Mr. FRANK FELLOWS, Mr. JAMES HEYWOOD, Professor LEONE LEVI, Dr. F. A. MAHOMED, Mr. J. E. PRICE, Lieut.-General PITT-RIVERS, Sir RAWSON W. RAWSON, *and* Mr. C. ROBERTS. *Associates*, Dr. T. G. BALFOUR, Dr. J. H. GLADSTONE, Inspector-General LAWSON, Dr. W. OGLE.[1] *Drawn up by* Mr. C. ROBERTS *and* Sir RAWSON W. RAWSON.

[PLATES IV.—X.]

1. THE Committee, originally appointed in 1875, and aided by successive grants, of which it has expended 280*l.*, has made a Report in each of the five years 1878 to 1882, and now submits its final Report.

2. Not that the work open to the Committee is exhausted, although it has to a great extent supplied what was pointed out in its Reports of 1881 and 1882 as chiefly wanting, or that its conclusions are to its own mind complete and satisfactory. But it would require more time and larger funds than are at the disposal of the Committee to prosecute its inquiries, even with the materials now in its possession, to the end which it has had in view; and the Committee is of opinion that the most useful course will be to bring before the Association the results of its past labours, indicating at the same time the conclusions which it considers to be sufficiently established by the facts ascertained, and the deficiencies, both of data and methods, which remain to be supplemented, either by individual exertion, or by the reappointment of a similar Committee at some future period under the auspices of the Association.

3. In order to furnish a complete review of the information obtained, it will be necessary to refer to tables and data contained in previous reports. A list of these Reports is furnished in a note.[2]

Objects and Operations of the Committee.

4. The Committee was appointed for the purpose of collecting observations on the systematic examination of the height, weight, and other physical characters of the inhabitants of the British Isles.

5. Its operations in each year are described in the introduction to its Report of 1881. The description and amount of the statistics which it has collected, and the names of the persons to whom it is indebted for the collection, are detailed chiefly at the commencement of its several Reports from 1880 to 1882.

6. Among the objects early aimed at by the Committee, and prosecuted by it up to the year 1881, was the collection and comparison of photographs of the typical races of the United Kingdom; but at the meeting of that year this inquiry was assigned to a separate Committee, upon whom will devolve the duty of reporting upon this branch of the general subject.

[1] The late Dr. William Farr was a member, and Chairman of the Committee from 1875 to 1879.

[2] 1, Report for 1878, 5 pp. (numbered pp. 182–6 in the Annual Report of the Association). 2, Report, 1879, 35 pp.; *ibid.* pp. 175–209. 3, Report, 1880, 41 pp.; *ibid.* pp. 120–59. 4, Report, 1881, 48 pp.; *ibid.* pp. 225–72. 5, Report, 1882, 3 pp.; *ibid.* pp. 278–80. An Index to the Tables is given in Appendix C.

7. The points to which the Committee has addressed its inquiries are—

(1) Stature.
(2) Weight.
(3) Girth of chest.
(4) Colour of eyes } Complexion.
(5) " hair }
(6) Breathing capacity.
(7) Strength of arm.
(8) Sight.
(9) Span of arms.

To these might have been added others, especially—

(10) Size and shape of head.
(11) Length of lower limbs as shown by the difference between the sitting and standing positions.
(12) Girth, length, and breadth of other parts of the body.

But the Committee was afraid of seeking to obtain more information than their contributors would be likely to furnish; and experience has shown that many of them have been unable to supply more than a portion of that which was requested. Few have furnished complete returns on all the subjects, but where one has failed another has succeeded, and sufficient data have been collected to give trustworthy statistical results on all the subjects of inquiry except those of breathing capacity and sight. An abstract of one of the complete returns will be given in its proper place, as exhibiting a good epitome of what the Committee has sought to obtain in all cases. (See Table XXIII.)

8. The large body of observations on stature, weight, and complexion collected by Dr. Beddoe, and those on stature, weight, and chest-girth collected by Mr. Roberts, previously to the formation of the Committee, have been made use of; and the Committee has thus had observations made on a total number of about 53,000 individuals of both sexes and of all ages, from which to construct their tables and to base their conclusions.

9. The statistics are unique in range and numbers, and have been obtained from a very large number of independent observers living in different parts of the country, without prejudice, and often in ignorance of the use which would be made of them; and they have been analysed and tabulated in a perfectly impartial manner, irrespective of all preconceived opinions. The Committee does not claim for them exemption from the liability to that amount of imperfection and probable error which must attach to all conclusions drawn from a disproportionate, and from a comparatively small number of observations. But great care has been taken in the examination and classification of all the returns to eliminate obvious errors, and to call attention in the body of the Report to any apparent discrepancies from faulty observation or deficient numbers.[1]

[1] 'If an exceedingly large number of measurements, weights, &c. be taken—supposing no bias, or any cause of error acting preferably in any one direction to exist—not only will the number of small errors vastly exceed that of large ones, but the results will be found to group themselves about the mean of the whole always according to one invariable law of numbers, and *that* the more precisely, the greater the total number of determinations. . . . Rude and unskilful measurements of any kind, accumulated in very great numbers, are competent to afford precise mean results. The only conditions are the continual *animus mensurandi*, the absence of

Methods.

10. The forms and instruments used have been explained in the Reports for 1878 and 1880; but practical difficulties have been found to exist in obtaining trustworthy observations with regard to breathing capacity. Experience has also led the Committee to believe that the use of Snellen's test-types for sight, Nos. 1 and 10, is more convenient, and will yield more trustworthy results, than that of the army test-dots, which were adopted in its original circulars.[1] Since 1879, also, the Committee has introduced the use of cards for recording the observations relating to single persons, which has been extensively adopted in Germany and the United States, and recently by the Investigation Committee of the British Medical Association, and which offers great facilities in analysing and grouping the facts observed. The Committee appends copies of the forms of the cards and of the methods of measurement and observation which they have employed. (See Appendix A.)

11. The difference between the *average* and *mean* of a number of observations, and its importance in dealing with the subjects under consideration, has been pointed out and discussed by Mr. Roberts in the Report for 1881, at p. 233;[2] and the special sense in which Mr. Roberts employs the term *mean*, being that value in an arithmetic series of observed values of which the observations are the most frequent, has been adopted by the Committee.[3]

12. In connection with the question of the applicability of the exponential law of error to statistical results relating to anthropometry, Mr. Francis Galton has contributed a valuable series of tables, with remarks, on the range in height, weight, and strength, in which he introduces his method of the calculation of deciles, quartiles, and medians.[4]

bias, the correctness of the scale with which the measures are compared, and the assurance that we have the entire range of error, at least in one direction, within the record.'—Sir J. F. W. Herschel, *Edin. Rev.* vol. xcii.

[1] See the Report for 1881 for a discussion of this subject by Mr. Lawson and Mr. Roberts.

[2] Also in a note at p. 121 of the Report for 1880.

[3] Mr. Roberts has followed Quetelet in the use of the word *mean*, and its difference from an *average* is thus explained by Sir John Herschel. Speaking of Quetelet's *homme moyen* he says:—'Now, this result, be it observed, is a *mean* as distinguished from an *average*. The distinction is one of much importance, and is very properly insisted on by M. Quetelet, who proposes to use the word mean only for the former, and to speak of the latter (average) as the "arithmetical mean." . . . . An average may exist of the most different objects, as of the height of houses in a town, or the size of books in a library. It may be convenient to convey a general notion of the things averaged, but involves no conception of a natural and recognised central magnitude, all differences from which ought to be regarded as deviations from a standard. The notion of a mean, on the other hand, does imply such a conception, standing distinguished from an average by this very feature, viz., *the regular march of the groups, increasing to a maximum and then again diminishing.* An average gives us no assurance that the future will be like the past. A mean may be reckoned on with the most implicit confidence. All the philosophical value of statistical results depends on a due appreciation of this distinction, and acceptance of its consequences.'—*Edin. Rev.* vol. xcii. Mr. Galton, however, desires to state that considering many statistical groups which are regular in their distribution are at the same time normally asymmetrical, he does not recognise the expressions of 'mean value' and 'the value most likely to be observed' as strictly equivalent.

[4] Report for 1881, p. 245.

TABLE I.—Showing the STATURE, WEIGHT, CHEST-GIRTH, and STRENGTH
Kingdom, arranged accord

STATURE														
Height without shoes		Scotland		Ireland		England		Wales		Total		Weight with clothes		Scotla
Inches	Mètres	No. of observations	No. per 1,000	No. of observations	No. per 1,000	No. of observations	No. per 1,000	No. of observations	No. per 1,000	No. of observations	No. per 1,000	lbs.	kilos.	No. of observations
77–	1·957	1	1	—	—	1	—	—	—	2	—	280	127·3	—
76–	1·931	4	3	—	—	1	—	—	—	5	1	270	122·7	—
75–	1·906	6	4	—	—	9	2	1	1	16	2	260	118·2	—
74–	1·881	15	12	—	—	16	2	1	1	32	3	250	113·6	4
73–	1·855	26	20	3	8	48	8	2	3	79	9	240	109·1	2
72–	1·830	69	53	10	29	117	19	6	8	202	24	230	104·5	4
71–	1·804	102	78	15	44	254	41	21	28	392	46	220	100·0	7
70–	1·779	115	88	25	72	473	76	33	45	646	75	210	95·5	14
69–	1·754	218	167	40	116	753	122	52	70	1063	124	200	90·9	24
Mean 68–	1·728	210	161	62	179	886	143	72	97	1230	143	190	86·4	67
67–	1·702	210	161	73	211	918	148	128	173	1329	155	180	81·8	125
66–	1·677	139	107	58	167	881	142	145	196	1223	143	170	77·3	168
65–	1·653	109	84	33	96	740	119	108	146	990	115	160	72·7	275
64–	1·626	47	36	15	44	524	85	83	112	669	78	150	68·2	255
63–	1·601	19	14	7	20	320	52	48	65	394	46	140	63·6	173
62–	1·575	9	7	2	6	128	20	30	41	169	20	130	59·1	63
61–	1·550	2	2	2	5	70	12	9	12	83	9	120	54·5	22
60–	1·525	2	1	—	—	39	6	—	—	41	5	110	50·0	8
59–	1·499	—	—	1	3	12	2	1	1	14	1	100	45·5	1
58–	1·474	1	1	—	—	3	1	—	—	4	1	90	40·9	—
57–	1·448	—	—	—	—	1	—	1	1	2	—	—	—	—
Total . .		1304	1000	346	1000	6194	1000	741	1000	8585	1000	Total . .		1212
Average inches ,, mètres		68·71 1·746	— —	67·90 1·726	— —	67·36 1·712	— —	66·66 1·694	— —	67·66 1·720	— —	Average lbs. ,, kilos.		165·3 75·1
Mean inches . . ,, mètres . .		68·5 1·741	— —	67·5 1·715	— —	67·5 1·715	— —	66·5 1·690	— —	67·5 1·715	— —	Mean lbs. . ,, kilos. .		160·0 72·7
Height÷weight inches per lb. of weight)		·416	—	·441	—	·435	—	·421	—	·428	—	Weight÷hgt. (lbs. per in. of height)		2·406

NOTE.—The factors in the bottom line give some means of ascertaining the most probable stature, weight, chest-girth, or strength of a man, when only one of these data is known. They also give modified values when the birthplace of the man is also known, whether it be in Scotland, Ireland, England, or Wales. The results so obtained are based on the supposition that the proportion between the values of these qualities is constant, which is practically true for values that do not differ widely from the mean.

The method of employing the factors is simple: thus, the first five of them are the number of inches in height divided by the number of pounds in

85 Adult Males (age from 23 to 50) of the Population of the United
Place of Birth.

WEIGHT								CHEST-GIRTH				STRENGTH				
Wales		England		Ireland		Total		Empty chest-girth: military measurement		Total: chiefly English		Strength: drawing-power, as in drawing a bow		Total: chiefly English		
observations	No. per 1,000	No. of observations	No. per 1,000	No. of observations	No. per 1,000	No. of observations	No. per 1,000	Inches	Centimètres	No. of observations	No. per 1,000	lbs.	kilos.	No. of observations	No. per 1,000	
	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	
	—	—	—	—	—	—	—	45–	114·3	4	1	—	—	—	—	
	—	1	—	—	—	1	—	44–	111·7	7	2	—	—	—	—	
	1	3	1	—	—	8	1	43–	109·2	20	6	—	—	—	—	
	—	9	2	—	—	11	2	42–	106·6	57	17	—	—	—	—	
	3	10	2	—	—	16	2	41–	104·1	76	22	150	68·2	4	3	
	2	33	6	—	—	41	5	40–	101·6	128	35	140	63·6	4	3	
	11	62	11	1	4	85	11	39–	99·0	216	63	130	59·1	2	2	
	9	75	13	1	4	107	14	38–	96·5	330	97	120	54·5	15	10	
	19	174	31	8	32	263	34	37–	93·9	442	130	110	50·0	18	12	
	46	304	55	13	53	476	61	36–	91·4	588	173	100	45·5	73	46	
	138	492	89	25	101	787	102	35–	88·9	552	162	90	40·9	226	140	
	182	881	158	36	146	1326	171	34–	86·3	541	158	80	36·4	296	184	
	242	1075	194	51	206	1559	201	33–	83·8	249	75	70	31·8	522	387	} Mean
	207	1240	223	57	231	1623	210	32–	81·2	117	35	60	27·3	250	157	
	92	694	125	42	170	867	112	31–	78·7	40	12	50	22·7	69	43	
	31	338	61	7	29	390	50	30–	76·2	33	10	40	18·2	15	10	
	13	133	24	1	4	152	20	29–	73·6	5	2	30	13·6	3	3	
	3	26	5	5	20	34	4	28–	71·1	1	—	—	—	—	—	
	—	2	—	—	—	2	—	27–	68·5	1	—	—	—	—	—	
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
3	1000	5552	1000	247	1000	7749	1000	Total . .		3407	1000	Total . .		1497	1000	
·3 ·9	— —	155·0 70·5	— —	154·1 70·0	— —	158·2 71·9	— —	Average ins. . „ cm. .		36·46 92·6	— —	Average lbs. „ kilos.		79·6 36·2	— —	
·0 ·5	— —	150·0 68·2	— —	150·0 68·2	— —	155·0 70·5	— —	Mean inches . „ cm. .		36·50 92·7	— —	Mean lbs. . „ kilos. .		77·5 35·2	— —	
·5	—	2·301	—	2·270	—	2·323	—	Girth÷hgt. Girth÷wgt.		·542 ·235	—	Stngth.÷ht. Stngth.÷wt.		1·182 ·513	— —	

weight, in the five following cases, natives of Scotland, Ireland, England, and Wales, and in the British Isles generally. The factor for Scotland is 0·416, consequently a Scotchman whose weight is 150 lbs. has most probably a height of 150 × 0·416 inches, or 62·4 inches. Similarly, in the next group of pounds of weight divided by inches of height, the factor for Englishmen is 2·301, consequently an Englishman 66 inches in height should weigh 66 × 2·301 lbs., or 152 lbs. In the same way we may calculate the other elements by the remaining factors.

Summary of Information Obtained.

13. The Committee submit in this, its final Report, a review of all the information which it has collected under the different heads of inquiry, giving references to those tables and conclusions which have been published in its previous Reports, and adding such others as it has been able to draw from the several sources at its command.

14. The first object of the Committee has been to ascertain the principal characteristics of the adult population:—

a. As to the stature, weight, chest-girth, and strength of the whole country and of each of its four provinces, shown in Table I., pages 256, 257.

b. The relative stature, weight, and strength of men and women. Table II., page 261.

c. The stature, weight, and complexion (colour of eyes and hair) of men in different counties as indicating their racial origin, and the influence of soil, climate, occupation, and other sanitary surroundings. Tables III. and IV., and Plates V.–IX., pages 262 to 265.

d. The relative stature of men of British origin, and that of other nationalities and races as far as they have been ascertained. Tables V. and VI., pages 268, 269.

15. The second object the Committee has had in view has been to ascertain the rate of growth and development of children of both sexes under different conditions of life (*media*); the period of the attainment of maturity; and the influence of advancing age on the physical condition of the body. Tables XII. to XXV.

Adult Population of the British Isles.

a. Adult Males—Table I.

16. Table I. shows the stature, weight, chest-girth, and strength of adult males of the ages from twenty-three to fifty years, the number of men at each measurement, and the ratio per thousand of the male population.

17. The observations are grouped according to the place of birth in England, Wales, Scotland, and Ireland; and, with the exception of the Irish, they were chiefly derived from the division of the country under which they are entered in the table. The Irish returns are almost entirely those of men born in Ireland, but living in England, Scotland, or Wales; and the Committee regrets that it has not been able to obtain more than one return direct from Ireland. The Scotch and Welsh by birth, living in England, have been entered under their respective nationalities. The columns are arranged in the order of the superiority of the average stature and weight.

18. The general results indicated by this table may be summarised as follows:—In height the Scotch stand first (68·71 inches; 1·746 mètres), the Irish second (67·90 inches; 1·726 mètres), the English third (67·36 inches; 1·712 mètres), and the Welsh last (66·66 inches; 1·694 mètres), the average of the whole being 67·66 inches (1·720 mètres). In weight the Scotch take the first place (165·3 lbs.; 75·1 kilos.), the Welsh the second (158·3 lbs.; 71·9 kilos.), the English the third (155·0 lbs.; 70·5 kilos.), and the Irish the fourth (154·1 lbs.; 70·0 kilos.), the average weight of the whole being 158·2 lbs. (71·9 kilos.). Thus the Scotch are the tallest and heaviest, the English take the third place in both tables, while the position of the Welsh and Irish is reversed—the

Irish, occupying the second place in stature, come last in weight, and the Welsh, though lowest in stature, stand second in weight. For each inch of stature a Scotchman weighs 2·406 lbs., a Welshman 2·375 lbs., an Englishman 2·301 lbs., and an Irishman 2·270 lbs.

19. The columns showing the number of individuals per thousand at each height, besides showing in a uniform manner the relative stature and weight of the different nationalities, will be useful to military surgeons for determining the minimum stature of recruits for the army. From the run of the figures it is obvious that if each country has to contribute its relative quota of soldiers, the minimum standard for Welsh recruits should be two inches lower, and for English and Irish recruits one inch lower, than for Scotch recruits. This difference in the relative stature is best shown by the black line running across the table, which marks the *mean* height—that is to say, the height at which the greatest number of observations occur in each nationality.

20. It is probable that too much importance has been attached to stature in selecting recruits for the army in this country, and that a high standard does not necessarily produce men best fitted for military duties. In the Report for 1879 are given two tables of the stature and weight of the English, Scotch, and Irish recruits for the years 1862–3, when the minimum standard of height was 66 inches (1·677 mètres), and in 1864–65, when it was reduced to 65 inches (1·626 mètres); and the result of this change was to lower the general average stature of English recruits by only 0·17 inch, of the Scotch by 0·21 inch, and the Irish by 0·25 inch, but in all three nationalities to increase the average weight—the English by 1·3 lbs., the Scotch by 6·7 lbs., and the Irish by 0·8 lb.

21. Although the minimum standard was the same for all the nationalities, the influence of race is indicated by the difference in the average stature of the recruits. The English and Welsh recruits (who were not distinguished from each other) were shorter in stature than the Irish by 0·30 inch, and the Scotch by 0·44 of an inch.[1]

22. The measurements of the chest given in Table I. are almost entirely those of Englishmen, and must be studied in connection with the English observations of height and weight; and the same remark applies to the figures relative to strength. The chest-girths were taken by the method adopted in the British army, and the strengths by the spring-balance introduced by this Committee, and described in Appendix A.

23. An examination of Table I. shows that an adult Englishman of typical proportions has a stature of 5 feet $7\frac{1}{2}$ inches; a chest-girth of $36\frac{1}{2}$ inches; a weight of 10 stones 10 lbs.; and is able to draw, as in drawing a bow, a weight of $77\frac{1}{2}$ pounds. These are the mean proportions. The averages give greater weight for height; they are:—Height, 5 feet $7\frac{1}{3}$ inches; weight, 11 stones 1 lb.; empty chest-girth, 36·46 inches; and strength, 79·6 lbs. For every variation of an inch in stature above or below the average, 2·301 lbs. weight, ·542 inch chest-girth, and 1·182 lbs. strength must be added or subtracted to keep up the typical proportions. This rule of proportion is, however, only approximately correct, as variations in the stature depend largely on the length of the lower limbs, while the other qualities depend chiefly on the size of the trunk. In ascending the scale of height, therefore, the above figures are probably a little too great, while in the opposite direction they are barely sufficient, but in either case they are sufficiently near for all practical

[1] Further tables relating to recruits are given in Appendix B to this Report.

purposes.[1] A further development of this rule as applicable to both sexes and at all ages will be found in Table XX.

24. Plate IV. shows the relative stature of the four British nationalities, traced from the columns in the table showing the number of men at each height per thousand. The curve of the English very nearly corresponds with that of the average for the whole kingdom. The Scotch curve is above the average, and from its irregularity it is evident that the observations on which it is based are not quite representative of that part of the kingdom. The Welsh curve is below the general average, and in a manner balances the excess of the Scotch, while the Irish curve is somewhat too acute, owing to the comparatively small number of observations on which it is based.

b. Adult Males and Females—Table II.

25. Table II. shows the relative stature, weight, and strength of adult males and females in England, no returns for females having been received from other parts of the kingdom. The average stature of adult males is 67·36 inches (1·712 mètres), and of females, 62·65 inches (1·592 mètres), showing a difference of 4·71 inches (·120 mètres), or nearly $4\frac{3}{4}$ inches. The average weight of males is 155·0 lbs. (70·5 kilos.), and that of females 122·8 lbs. (55·8 kilos.), showing an excess of 32·2 lbs. (14·7 kilos.), or about $2\frac{1}{3}$ stones on the side of males, the percentage difference of weight being just threefold that of height. The ratio between the stature of men and women in England is as 1 to 0·930, or as 16 to 14·88, the difference being somewhat greater than in Belgium, where, according to Quetelet, the ratio is as 1 to 0·937, or about 16 to 15 (strictly 16 to 14·99). The observations of the strength of females were obtained from pupils in training institutions for schoolmistresses and from shop assistants, and the average is no doubt much lower than if the labouring classes were also represented. The difference of strength is 35 lbs., the females being little more than half as strong as males. In these tables, the age of the attainment of maturity is fixed at 23 years for males, and 20 years for females, the reasons for which will be explained in another part of the Report.

[1] The following measurements show the difference between the height of the body of men in the standing and recumbent positions, and the span of arms measured across the front of the chest. Also the difference between the height of the body in the standing and the sitting positions, showing the relative length of the trunk and of the lower limbs. The English figures are calculated from the American measurements of Dr. Hitchcock, taken in 1882.

	Age years	No. of obs.		Standing height	Horizontal length	Span of arms	Sitting height	
American Amherst College	21·5	327	mètres	1·729	1·748	1·787	0·907	Length of trunk and head
			inches	68·07	68·82	70·36	35·71	
English Professional class	21·5	364	mètres	1·746	1·765	1·804	·915	
			inches	68·70	69·45	71·01	36·04	
Difference	American		mètres	—	+·019	+·058	−·822	Length of lower limbs
			inches	—	+·75	+2·29	−32·36	
	English		mètres	+·017	+·019	+·058	−·831	
			inches	+·63	+·75	+2·31	−32·66	

The ratio between the total height and the sitting height is 1 to 1·906.

Plate IV

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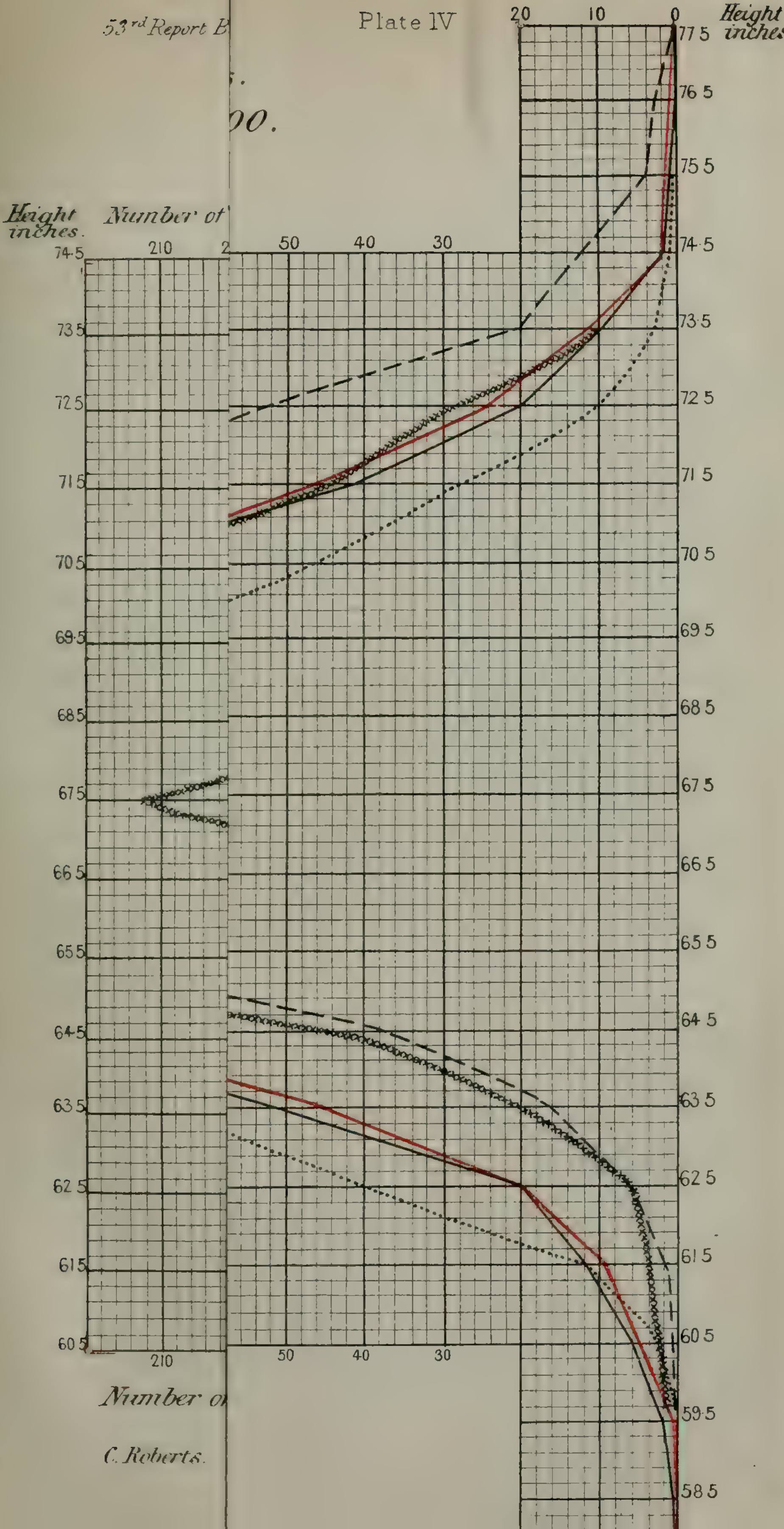
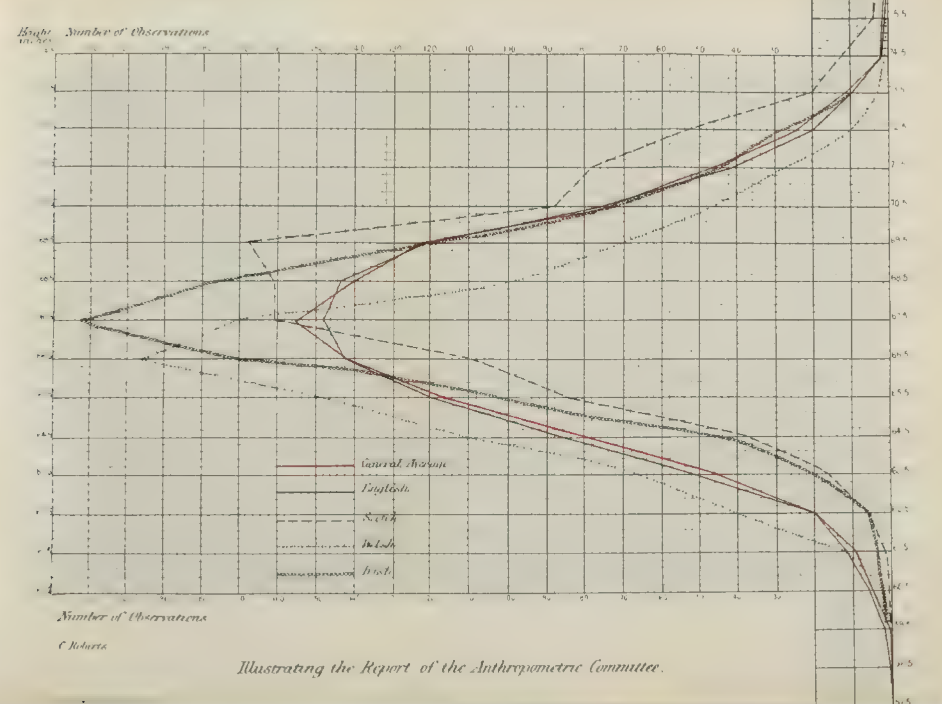
00.



C. Roberts.

Diagram showing the observed Stature of Adult Males of British Isles.
Traced from the columns of Table 1. showing the number per 1000.



C. Roberts

Illustrating the Report of the Anthropometric Committee.

TABLE II.—Showing the Relative STATURE, WEIGHT, and STRENGTH of Adult Males (23–50 years) and Females (20–50 years) of English Origin.

Height				Weight				Strength			
Height without shoes		Number of observations		Weight with clothes		Number of observations		Strength, drawing-power		Number of observations	
Inches	Mètres	Males	Females	lbs.	Kilos.	Males	Females	lbs.	Kilos.	Males	Females
77–	1·957	1	—	260	118·2	1	—	—	—	—	—
76–	1·931	1	—	250	113·6	3	—	—	—	—	—
75–	1·906	9	—	240	109·1	9	—	—	—	—	—
74–	1·881	16	—	230	104·5	10	—	150	68·2	4	—
73–	1·855	48	—	220	100·0	33	—	140	63·6	4	—
72–	1·830	117	—	210	95·5	62	—	130	59·1	2	—
71–	1·804	254	1	200	90·9	75	1	120	54·5	15	—
70–	1·779	473	—	190	86·4	174	—	110	50·0	18	—
69–	1·754	753	—	180	81·8	304	1	100	45·5	73	—
68–	1·728	886	3	170	77·3	492	—	90	40·9	226	1
Mean 67–	1·702	918	11	160	72·7	881	2	80	36·4	296	—
66–	1·677	881	22	150	68·2	1075	14	70	31·8	522	2
65–	1·653	740	24	140	63·6	1240	20	60	27·3	250	5
64–	1·626	524	44	130	59·1	694	58	50	22·7	69	25
63–	1·601	320	57	120	54·5	338	101	40	18·2	15	101 Mean
62–	1·575	128	71	110	50·0	133	108	30	13·6	3	98
61–	1·550	70	59	100	45·5	26	53	20	9·1	—	9
60–	1·525	39	37	90	40·9	2	10	—	—	—	—
59–	1·499	12	22	—	—	—	—	—	—	—	—
58–	1·474	3	17	—	—	—	—	—	—	—	—
57–	1·448	1	6	—	—	—	—	—	—	—	—
56–	1·423	—	3	—	—	—	—	—	—	—	—
55–	1·398	—	2	—	—	—	—	—	—	—	—
Total number of observations		6194	379	—		5552	368	—		1497	241
Average inches / mètres		67·36 / 1·712	62·65 / 1·592	Average lbs. / kilos		155·0 / 70·5	122·8 / 55·8	Average lbs. / kilos		79·6 / 36·2	44·5 / 20·2
Mean inches / mètres		67·50 / 1·715	62·5 / 1·588	Mean lbs. / kilos		150·0 / 68·2	120·0 / 54·6	Mean lbs. / kilos		77·5 / 35·2	40·0 / 18·2

c. Distribution of Adult Males according to Stature, Weight, and Complexion. Table III., and Plates V.–IX. (Maps Nos. 1 to 5).

26. Table III. exhibits the average stature, weight, and complexion (colour of eyes and hair) of adult males born in the several counties of Great Britain and Wales and in each province of Ireland, arranged in the order of the greatest stature. The Committee is sensible that the number of observations in some of the counties is not sufficient to furnish an average which may be fully relied upon; but the results, as detailed in the remarks upon this summary, show that there is such a consistency between the data and the records of history as to justify a general trust in the conclusions to be drawn from the figures.

TABLE III.—Showing the STATURE, WEIGHT, and COMPLEXION of 8,614 Adult Males (age from 23 to 50) of the Population of the United Kingdom, arranged according to birthplace in Counties in the order of greatest Stature. Illustrated by Maps.

Counties	Number of obs.	Average height without shoes: Inches	Average height without shoes: Mètres	Average weight, including clothes: lbs.	Average weight, including clothes: Kilos	Ratio, lbs. weight per inch of stature Weight ÷ Height	Light blue, blue, dark blue, and grey eyes, with: Very fair, light brown, or brown hair	Black or dark brown hair	Golden or red hair	Total Fair eyes	Brown, hazel, or black eyes, with: Brown, dark brown, and black hair	Fair hair	Red and dark red hair	Total Dark eyes	Other combinations, such as green, light brown eyes with light or dark hair
							per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
SCOTLAND. Total	1369	68·71	1·746	165·3	75·1	2·406	46·1	21·9	4·2	75·2	22·0	0·9	1·1	24·0	0·8
Kirkcudbright, Ayrshire, and Wigton	124	70·14	1·782	172·9	78·6	2·465	43·4	25·6	3·3	72·3	27·0	—	—	27·0	0·7
Edinburgh, Linlithgow, Haddington, and Berwickshire	60	69·60	1·769	178·6	81·2	2·551	51·5	25·8	1·0	78·3	15·5	—	3·1	18·6	3·1
Perth, Stirling, and Dumbarton	46	69·13	1·757	172·9	78·5	2·501	40·9	22·0	7·1	70·0	26·0	—	3·2	29·2	0·8
Sutherland, Ross, Cromarty, and Skye	63	68·76	1·747	169·8	77·2	2·469	45·2	26·0	2·9	74·1	23·1	1·9	0·9	25·9	—
Fife, Kinross, and Clackmannan	82	68·65	1·745	162·7	73·9	2·370	38·4	28·8	4·1	71·3	23·3	4·1	1·3	28·7	—
Argyle, Bute, and Arran	97	68·63	1·744	177·0	80·4	2·579	42·9	22·1	5·7	70·8	24·3	0·7	2·1	27·1	2·1
Dumfries, Roxburgh, Selkirk, and Peebles	113	68·59	1·741	161·6	73·4	2·356	43·0	32·4	5·6	81·0	17·6	—	0·7	18·3	0·7
Inverness-shire	88	68·45	1·740	166·3	75·5	2·429	44·2	26·6	3·2	74·0	24·7	1·3	—	26·0	—
Lanark and Renfrew (including Glasgow)	189	68·21	1·734	151·4	68·8	2·219	52·8	17·6	3·2	73·6	24·6	0·4	1·0	26·0	0·4
Caithness	39	68·22	1·734	168·1	76·4	2·464	37·5	27·5	7·5	72·5	17·5	2·5	2·5	22·5	5·0
Forfar and Kincardine	65	68·07	1·728	159·9	72·7	2·349	51·7	29·3	2·6	83·6	14·6	0·9	—	15·5	0·9
Islay and Colonsay	109	68·04	1·728	171·3	77·8	2·517	38·0	43·4	9·7	91·1	8·0	0·9	—	8·9	—
Aberdeen, Banff, Elgin, and Nairn	109	68·04	1·728	165·9	75·4	2·438	40·1	24·0	2·1	66·2	28·9	2·1	1·4	32·4	1·4
Shetland	108	67·92	1·726	155·9	70·8	2·295	62·4	11·1	4·3	77·8	21·4	0·8	—	22·2	—
Hebrides—Harris and Uist	77	67·91	1·726	169·1	76·8	2·490	—	—	—	—	—	—	—	—	—
ENGLAND. Total	6194	67·36	1·712	155·0	70·5	2·301	40·4	19·6	3·1	63·1	31·5	1·6	0·6	33·7	3·2
Yorkshire, North and East Ridings	231	69·00	1·754	164·0	74·5	2·377	40·5	20·5	5·6	66·6	23·8	2·9	0·3	27·0	6·4
Northumberland	291	68·59	1·743	161·4	73·3	2·353	43·2	23·8	7·3	74·3	20·5	0·8	0·4	21·7	4·0
Cumberland and Westmoreland	272	68·37	1·737	158·6	72·1	2·320	41·4	25·3	1·1	67·8	28·9	—	0·4	29·3	2·9
Lincolnshire	200	68·16	1·732	162·9	74·0	2·390	34·5	23·7	2·8	61·0	32·8	1·1	2·3	36·2	2·8
Norfolk	123	68·00	1·728	160·1	72·7	2·353	41·7	22·2	2·6	66·5	26·3	2·3	1·1	29·7	3·8
Essex	133	67·95	1·727	156·9	71·3	2·309	26·4	26·4	4·4	57·2	35·9	0·6	0·6	37·1	5·7
Cornwall	305	67·91	1·726	161·4	73·4	2·376	39·2	18·8	2·1	60·1	32·3	2·8	0·3	35·4	4·5

Staffordshire	87	67·82	1·724	160·5	72·9	2·366	45·1	17·0	2·6	64·7	31·1	—	—	31·4	3·9
Derbyshire	61	67·80	1·723	157·5	71·6	2·323	44·9	27·0	4·5	76·4	19·1	3·4	—	22·5	1·1
Suffolk	164	67·71	1·720	160·2	72·8	2·366	27·2	22·8	4·3	54·3	32·3	5·2	1·3	38·8	6·9
Durham	95	67·70	1·720	153·0	74·1	2·260	48·2	18·0	5·8	72·0	25·2	2·1	0·7	28·0	—
Berkshire	92	67·66	1·718	156·2	71·0	2·308	38·6	16·9	1·2	56·7	36·1	2·4	—	38·5	4·8
Kent	228	67·62	1·718	157·1	71·4	2·323	41·9	14·1	1·1	57·1	38·5	1·1	—	39·6	3·3
Lancashire	243	67·50	1·715	151·7	68·9	2·247	45·8	16·4	1·8	64·0	32·9	0·8	1·0	34·7	1·3
Hampshire	166	67·45	1·714	155·2	70·5	2·301	40·2	15·7	1·2	57·1	37·4	0·8	0·8	39·0	3·9
Nottinghamshire	156	67·38	1·712	153·9	69·9	2·284	44·6	17·5	2·6	64·7	32·8	1·0	1·0	34·8	0·5
Leicester and Rutland	90	67·29	1·709	155·3	70·6	2·308	34·4	16·3	—	50·7	44·4	1·2	0·6	46·2	3·1
Northamptonshire	136	67·26	1·709	156·1	71·0	2·321	40·7	20·7	2·6	64·0	29·4	3·3	—	32·7	3·3
Sussex	147	67·26	1·709	159·5	72·5	2·371	34·8	18·5	6·2	59·5	35·7	0·9	—	36·6	3·9
Worcestershire	65	67·22	1·708	157·6	71·6	2·344	33·1	18·5	3·2	54·8	43·6	—	—	43·6	1·6
Warwickshire	123	67·12	1·707	149·1	67·7	2·222	37·5	17·7	2·1	57·3	37·8	2·8	0·7	41·3	1·4
Bedfordshire	75	67·07	1·704	157·9	71·8	2·354	35·6	13·7	2·8	52·1	43·8	—	—	43·8	4·1
Devonshire	218	67·08	1·704	156·9	71·2	2·339	43·0	20·0	2·8	65·8	28·8	3·2	0·5	32·5	1·7
Dorsetshire	73	67·00	1·702	158·1	71·8	2·360	35·3	23·0	1·6	59·9	32·8	1·6	0·8	35·2	4·9
Yorkshire, West Riding (including Sheffield)	453	66·98	1·702	152·6	69·3	2·278	42·1	19·2	6·4	67·7	29·6	1·5	0·2	31·3	1·0
London	259	66·92	1·701	152·9	69·5	2·285	36·3	17·2	2·4	55·9	32·3	0·5	2·0	34·8	9·3
Cambridge and Huntingdonshire	122	66·75	1·696	155·3	70·6	2·325	39·9	11·2	2·8	53·9	44·7	—	0·7	45·4	0·7
Oxfordshire and Buckingham	72	66·74	1·696	151·8	69·0	2·275	40·8	21·7	0·8	63·3	34·2	0·8	—	35·0	1·7
Cheshire	37	66·50	1·690	150·9	68·6	2·269	43·2	18·0	5·0	66·2	30·2	—	0·7	30·9	2·8
Surrey (exclusive of London)	270	66·47	1·689	146·5	66·6	2·204	45·4	19·8	1·8	67·0	30·1	1·0	0·3	31·4	1·6
Hereford and Monmouth	23	66·45	1·688	154·0	70·0	2·317	41·7	22·3	1·0	65·0	29·1	1·0	1·0	31·1	3·9
Wiltshire	141	66·34	1·686	158·2	71·9	2·384	42·8	26·2	0·9	69·9	28·4	—	0·4	28·8	1·3
Shropshire	60	66·33	1·685	149·4	67·9	2·252	40·8	15·7	1·4	57·9	36·7	—	3·4	40·1	2·0
Gloucestershire (including Bristol)	336	66·31	1·685	148·3	67·4	2·236	50·3	14·3	2·2	66·8	30·2	1·4	—	31·6	1·6
Somersetshire	447	66·30	1·685	149·1	67·8	2·249	38·9	17·4	4·9	61·2	30·3	3·4	0·7	34·4	4·4
Hertfordshire and Middlesex (exclusive of London)	160	66·27	1·684	152·5	69·2	2·301	29·0	36·3	2·0	67·3	23·8	0·8	—	24·6	8·1
Wales. Total	735	66·66	1·694	158·3	71·9	2·375	34·4	21·2	8·7	64·3	26·8	4·2	1·1	32·1	3·6
Flint and Denbigh	82	67·06	1·703	160·7	73·1	2·396	29·5	18·9	11·6	60·0	26·3	5·3	—	31·6	8·4
Carnarvon, Anglesea, Merioneth, and Montgomery	82	66·85	1·699	162·5	73·8	2·431	35·9	12·8	5·1	53·8	41·1	—	—	41·1	5·1
Cardigan	389	66·61	1·693	155·9	70·9	2·340	30·9	23·0	13·0	66·9	27·9	3·7	1·5	33·1	—
Brecon and Radnor	60	66·58	1·692	158·2	71·9	2·391	42·0	20·3	1·4	63·7	33·3	—	1·5	34·8	1·5
Glamorgan, Caermarthen, and Pembroke	122	66·47	1·689	155·4	70·6	2·339	39·6	20·8	3·2	63·6	21·2	6·4	0·8	28·4	8·0
Ireland. Total	346	67·90	1·726	154·1	70·0	2·270	48·1	19·3	2·5	69·9	23·7	0·8	1·1	25·6	4·5
Connaught } 277	35	68·73	1·746	154·9	70·2	2·253	59·0	24·1	1·2	84·3	13·3	—	1·2	14·5	1·2
Munster	55	68·52	1·741	153·0	69·5	2·233	36·8	24·0	4·8	65·6	24·0	0·8	—	24·8	9·6
Ulster	44	68·41	1·739	157·9	71·8	2·308	49·4	24·7	—	74·1	22·2	1·2	—	23·4	2·5
Leinster	143	68·21	1·734	149·4	67·9	2·181	50·3	11·5	7	64·5	28·9	1·1	2·2	32·2	3·3

27. To save much detailed description, the Committee has thought it desirable to illustrate Table III. by a series of shaded maps (Plates V.–IX.), which present at once to the eye the relative distribution of the stature, weight, and complexion of the adult male population in the several counties of Great Britain and in each province of Ireland.

Map No. 1 shows the distribution of the average stature (without shoes) of adult males, in degrees of half an inch each from 66 to 70 inches. The darkest shade represents the shortest stature.

Map No. 2 shows the distribution of the average weight (including the clothes) of adult males, in degrees of five pounds from 145 pounds to 180 pounds. The darkest shade represents the lightest weight.

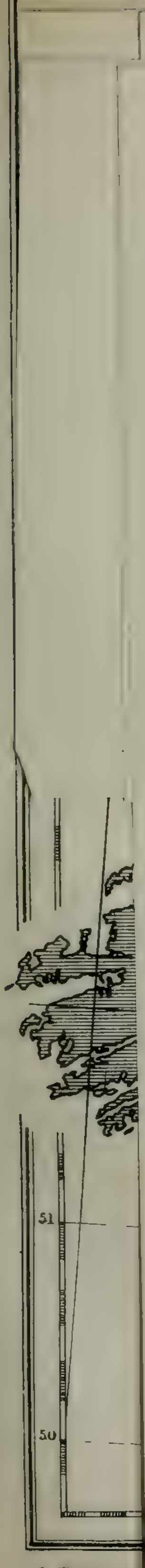
Map No. 3 shows the distribution of adult males with fair complexion, i.e. blue and grey eyes with fair, light-brown, brown, and light-red hair. The darkest shade represents the lowest percentage of fair complexion.

Map No. 4 shows the distribution of adult males with dark complexion, i.e. brown and black eyes, with brown, dark brown, dark red, and black hair. The darkest shade represents the highest percentage of dark complexion, or its greatest prevalence.

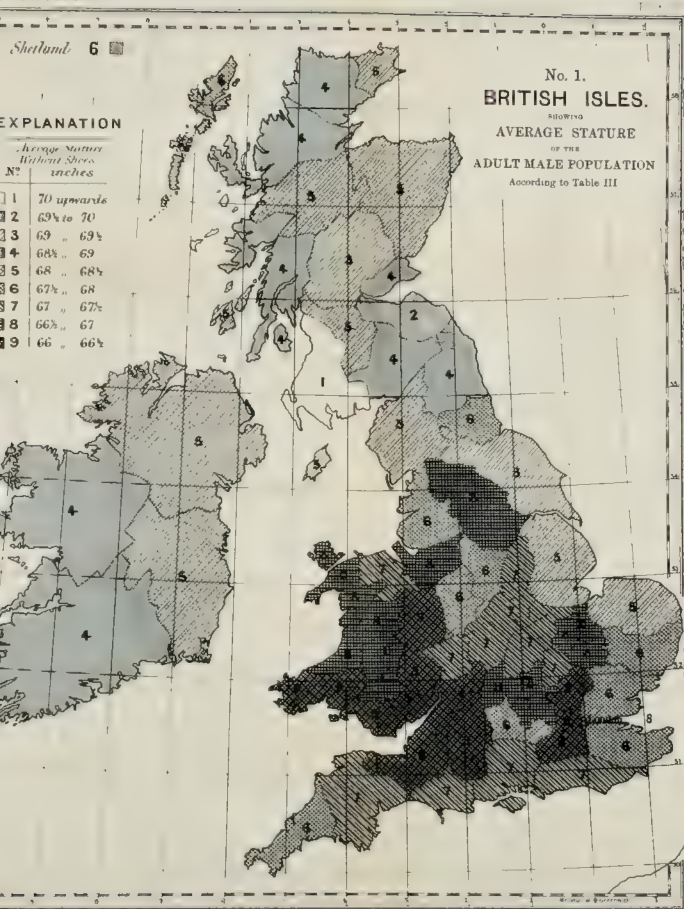
Map No. 5 shows the distribution of adult males with mixed complexion, i.e. blue and grey eyes with dark brown and black hair. The darkest shade represents the highest percentage, or the greatest prevalence of this complexion.

28. As the observations were necessarily made on a limited number of individuals, and as doubts may exist as to whether the results can be accepted as representing the whole of the male population at the ages specified, the counties having similar statures have been grouped together, and the male population for each group ascertained from the Census returns of 1881.[1] The average stature worked out from these figures is 67·58 inches, while that obtained from the actual observations on 8,585 individuals, given in Table I., is 67·66 inches, the difference between the two being only 0·08 of an inch. Table IV. shows the grouping of the counties, having the same stature according to the Committee's returns, and the total male population of each group at the ages from 25 to 55 years.

[1] These returns for England and Scotland are not yet published, and the Committee is indebted to the courtesy of the Registrars-General of those portions of the kingdom for manuscript copies of the returns. The ages of the men on whom the observations were made are not exactly the same as those obtained from the Census office, but they are sufficiently near for any practical purpose. The measurements were made on men from 23 to 51 years of age, while the Census returns are those of men from 25 to 55 years, but the four years above 51 will about compensate for the two years wanting below 25 years both in numbers and stature, in consequence of losses by death. Both periods correspond with the best portion of men's lives, at least as far as stature is concerned.



C. Roberts



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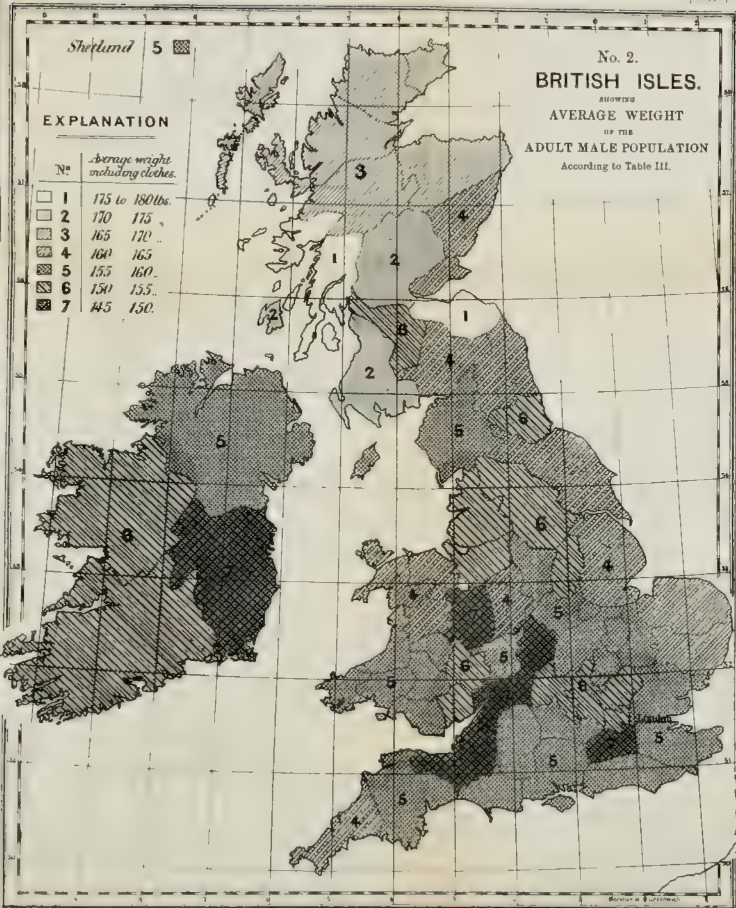


Illustrating the Report of the Anthropometric Committee

TABLE IV.—Showing the Number of Adult Males of the Ages above 25 and under 55 years for each group of counties possessing the same AVERAGE STATURE, and the ratio per 1,000. From the Census returns of 1881.

Observed average stature without shoes in inches	Counties of the United Kingdom	Adult male population age 25–55 years	Per 1,000
69½ and upwards	Kirkcudbright, Ayr, Wigton; Edinburgh, Linlithgow, Haddington, Berwickshire.	125,103	22·2
69 to 69½	Sutherland, Ross and Cromarty, Skye, Perth, Stirling, Dumbarton, Fife, Kinross, Clackmannan; North and East Ridings of Yorkshire.	167,914	30·0
68½ to 69	Argyle, Bute, Arran, Dumfries, Roxburgh, Selkirk, Peebles; Northumberland; Connaught, Munster.	459,055	81·7
68 to 68½	Caithness, Inverness, Aberdeen, Banff, Elgin, Nairn, Forfar, Kincardine; Lanark, Renfrew; Cumberland, Westmoreland; Lincoln, Norfolk; Ulster, Leinster.	974,177	173·4
67½ to 68	Shetland, Western Hebrides; Durham, Lancashire, Derby, Stafford; Suffolk, Essex, Kent; Berkshire; Cornwall.	1,326,292	236·0
67 to 67½	Nottingham, Leicester, Rutland, Northampton, Bedford; Warwick, Worcester; Flint, Denbigh; Sussex, Hampshire, Dorset, Devon.	688,465	122·6
—	London (66·92 inches).	667,118	118·7
66½ to 67	West Riding of Yorkshire, Chester; Carnarvon, Anglesea, Merioneth, Montgomery, Cardigan, Brecon, Radnor; Cambridge, Huntingdon; Buckinghamshire, Oxfordshire.	636,769	113·3
66 to 66½	Hertford, Middlesex (ex. metrop.); Surrey (ex. metrop.); Shropshire, Hereford, Monmouth, Gloucester, Wiltshire, Somerset; Glamorgan, Caermarthen, Pembroke.	573,774	102·1
		5,618,677	1000·

$$\frac{\text{Stature} \times \text{Population}}{\text{Total male population}} = \left\{\begin{array}{l}\text{67·58 inches, average stature of adult males (25–55 years}\\ \text{of age) of the United Kingdom.}\end{array}\right.$$

29. *Ethnology.*—The variations in stature, weight, and complexion shown to exist in different districts of the British Isles by the maps, appear to be chiefly due to difference of racial origin, and this influence predominates over all others. 'We have reason to believe, from historical and antiquarian researches, that the ancient Caledonii, the Belgæ and Cimbri, and the Saxons and Frisians, as well as the Danes and Normans, were all people of great stature. On the other hand, the prehistoric (neolithic) race or races in Britain appear to have been of low or moderate stature. Accordingly the higher statures are found in the Pictish or

Cimbro-British districts of Galloway; in the Anglo-Danish ones of North and East Yorkshire, Westmoreland and Lincolnshire, and in Cumberland, whose people are ethnologically intermediate between the two. Lothian and Berwickshire are mainly Anglian, while the Perthshire Highlanders are the most clearly identified as the descendants of the Caledonii. The high position of Norfolk in the list is due to a large admixture of Danish blood on the coast. There is a fringe of moderately high stature all round the coast from Norfolk to Cornwall, while the inland people, retaining more of the ancient British blood, yield lower averages. Middlesex and Hertfordshire, which stand very low, were later and less perfectly colonised by the Anglo-Saxon than the surrounding counties, and nearly the same may be said of the counties around the Severn estuary and the Welsh border. Cornwall stands higher than the surrounding counties, and this is probably due to its having become the refuge of the military class of Southern Britain, in the main of Belgic origin. Flint and Denbigh owe their superiority to the other Welsh counties to the immigration of the Cumbrian and Strathclyde Britons.' —Dr. Beddoe.

30. According to the Committee's returns, the western provinces of Ireland possess a high stature, similar to the Scotch Highlands, with which they may have a common racial origin, while the lower stature of the eastern provinces is probably traceable to the comparatively recent Scotch and English immigrations. The Irish returns are, however, too few to be relied on (although the closeness of the averages for all the provinces would suggest the absence of any errors of observation), and any conclusions drawn from them must be received with great reserve until they are confirmed by more extended inquiries. In some of the returns the county origin and birthplace was not recorded, which accounts for the difference between the totals for the whole of Ireland and those living in each province.

31. The racial elements of the British population are best demonstrated by separating a few of the counties where there has been the least admixture of foreign blood, and comparing these together, thus:—

Race	District	Stature	Weight
Early British	Cardigan, Radnor, and Brecon	66·59	169·3
Saxon	Sussex, Berkshire, and Oxfordshire	67·22	155·8
Anglian	Lothians, Northumberland, and Norfolk	68·73	166·7
Scandinavian	Shetland, Caithness, North and East Yorkshire, and Lincolnshire.	68·32	162·7

32. *Geographical distribution.*—The inhabitants of the more elevated districts possess a greater stature than those of alluvial plains. The counties forming the river valleys of the Severn and Wye, the Thames, the Dee and Mersey, the Clyde, the Trent, and the fen district of Cambridge and Huntingdon, show a lower stature than the surrounding counties inhabited by persons of a similar racial origin.

33. With respect to latitude and climate, the inhabitants of the northern and colder districts possess greater stature than those of the southern and warmer parts of the island; those of the north-eastern and drier regions are taller than those of the south-western and damper climates. A similar disposition of stature has been found to exist in France and Italy, the

inhabitants of both these countries being taller in the northern than in the southern provinces. The same rule applies to the whole of the countries of Europe, in their relation to each other, as will be seen in Table IV., constructed to show the position held by the inhabitants of the British Isles relative to the stature of other European countries. The Committee regrets that it has not been able to obtain any information on this subject direct from the European countries (except some referring to conscripts, which were not suitable for their purpose), and has been obliged to avail itself of the observations made in the United States of America on emigrants from European States. In reading this table it must be borne in mind that the statistics referring to the United Kingdom, collected by the Committee, and to the native-born population of the United States, refer to men of all classes; while those collected by the military authorities of 1863–4 in the United States, referring to Canada and the other American countries, and to those of all Europe, refer to emigrants, who belong almost entirely to the labouring classes. The close accord between the average stature of the United Kingdom (67·66 inches) and that of the native white population of the United States (67·67 inches) is accounted for in this way; and, on the other hand, the marked differences between the statures of the Scotch (68·71), Irish (67·90), English (67·36), and Welsh (66·66 inches), as given by the Committee and those given by the United States Government (67·07, 66·74, 66·58, and 66·42 respectively) is explained. Some American writers on the subject have overlooked this important distinction, and, studying only the statistics obtained in their own country, have concluded that the Anglo-Saxon race is of greater stature in America than in Great Britain. In the Report of the Committee for 1879 Mr. Roberts has given a paper, illustrated by a series of diagrams and statistical tables, of English and Americans, showing the close similarity which exists between the stature and weight of the two branches of our race, both in children and adults; and the more extended observations of the Committee appear to confirm his conclusions.

34. *Occupation and sanitary surroundings.*—The various industries of this country are not often so defined by the county boundaries as to show their effects on the physical development. It is probable, however, that the low stature in the West Riding of Yorkshire is due to the large manufacturing town population included in the returns, and the relatively low stature of Durham to the large mining population. Lancashire and Stafford, which contain similar industries to those of the West Riding and Durham, do not show any falling off in stature, and it is probable that a large number of returns received from Sheffield have unfairly lowered the West Riding. The very low position, lower than can be accounted for by their racial origin, taken by the home counties—Hertford, Middlesex, and Surrey—is no doubt due to their proximity to London; the more vigorous men are attracted to the town by high wages, and the more feeble overflow into the surrounding districts. The counties which fringe the sea-coast possess a higher stature than those adjoining them but lying further inland. This may be due to race, as has already been suggested; but it may also be due to the more healthy situation or the fishing occupation. The lower stature of the river valleys would seem to imply that such situations are not favourable to physical development, especially as some of them were originally settled by the Scandinavian races.

TABLE V.—Showing the Average STATURE of Adult Males in each Division of the United Kingdom, according to the returns collected by the Anthropometric Committee, compared with that of Adult Males of American and European Origin, who were examined for admission into the United States Army in the year 1863–4; the natives of European origin being arranged in the order of their average stature, showing also the medium stature, and the proportions above and below it, with the proportions of the extremes of high and low stature. (See 'Statistics, Medical and Anthropological, U.S. Army, 1875.')

Countries	No. of observations	Average stature. Inches	Percentage proportion of total number			Extremes. Percentage proportion of total number	
			Under 65 inches	65 to 69 inches	Above 69 inches	Under 61 inches	Above 73 inches
Observations of Anthropometric Committee:—							
Scotland	1,304	68·71	5·6	50·2	44·2	0·19	2·13
Ireland	346	67·90	6·7	65·3	28·0	0·32	0·00
England	6,194	67·36	17·8	55·5	26·7	0·93	0·43
Wales	741	66·66	22·8	62·0	15·2	—	—
Total, United Kingdom	8,585	67·66	16·1	55·7	28·2	—	—
Observations on Conscripts in U.S. America:—							
United States.							
White, native born	315,620	67·67	15·3	54·1	30·6	0·53	2·02
Coloured, of all degrees	25,828	66·63	29·6	51·9	18·5	1·79	1·00
Indians, N.A. tribes	121	67·93	14·2	52·0	33·8	—	0·08
Immigrants from—							
Canada (chiefly French)	21,645	67·01	21·8	56·3	21·9	0·74	1·01
Mexico	91	66·11	25·2	51·7	13·1	3·29	1·09
South America	79	65·90	41·7	40·4	17·9	2·13	—
West Indies	580	66·31	28·9	56·4	14·7	0·86	0·34
Europe.							
Norway	2,290	67·47	16·6	57·0	26·4	0·74	1·31
Scotland	3,476	67·07	20·4	58·3	21·3	0·46	1·03
Sweden	1,190	66·90	21·3	59·5	19·2	0·42	0·76
Ireland	30,557	66·74	23·2	60·1	16·7	0·70	0·49
Denmark	383	66·65	25·1	57·7	17·2	0·78	0·26
Holland	989	66·64	26·6	56·3	17·1	1·31	0·50
England	16,196	66·58	25·9	58·3	15·8	1·08	0·56
Hungary	89	66·58	22·5	58·4	19·1	3·37	1·12
Germany	54,944	66·54	27·0	57·0	16·0	1·31	0·51
Wales	1,104	66·42	29·3	53·6	17·1	0·82	0·63
Russia	122	66·39	29·6	54·0	16·4	3·28	0·82
Switzerland	1,302	66·38	29·5	55·7	14·8	1·61	0·44
France	3,243	66·28	30·0	56·5	13·5	1·85	0·57
Poland	171	66·21	32·1	56·7	11·2	1·75	1·17
Italy	339	66·00	37·8	48·9	13·3	2·06	0·29
Spain	148	65·64	43·3	49·3	7·4	2·70	—
Portugal	81	65·43	39·5	56·8	3·7	3·70	—

d. British compared with other Races and Nationalities.

35. Considering the large number of different races included in the British Empire, and the political and commercial relations of its people with nearly every other country, the Committee think it will be interesting and useful to give a table showing the average stature of the different races and nationalities of the world, as far as it has been able to ascertain them from published records. The list is very imperfect, and it is probable that many of the measurements need revision by more extensive observation. No nation is so favourably situated for revising and completing the list as our own; and the Committee hope that the table will be instrumental in promoting further observations of the kind, especially by medical officers in the Navy and Army, and others practising in our numerous colonies and dependencies. It is interesting to find that, with the exception of a few imperfectly-observed South Sea Islanders, and whose actual numbers, if the measurements are correct, are very few, the English professional classes head the long list, and that the Anglo-Saxon race takes the chief place in it among the civilised communities, although it is possible it might stand second to the Scandinavian countries if a fair sample of their population were obtained.

TABLE VI.—Showing the STATURE of Adult Males of the British Isles relative to that of other Races and Nationalities, arranged in the order of greatest Stature.

Race or Nationality			Authority	Mètres	Ft. in.
Polynesians	Samoa	1·853	Lapeyrouse	1·762	5– 9·33
	Tahiti and Pitcairn	1·782	Garnot, Beechey		
	Marquesas	1·763	Porter, Cook, &c.		
	New Zealand	1·755	Various		
	Polynesians	1·753	Wilkes, *Novara*		
	Sandwich	1·731	Lesson, Rollin		
English professional class			Anthropometric Com.	1·757	5– 9·14
Patagonians		1·778	Musters	1·754	5– 9·00
		1·730	D'Orbigny		
Angamis of the Naga Hills			Woodthorp	1·754	5– 9·00
Negroes of the Congo			Topinard	1·752	5– 8·95
Scotch, all classes (recruits, 5 ft. 8·03)			Anthropometric Com.	1·746	5– 8·71
Amakosa Kaffirs, South Africa			Sir A. Smith	1·741	5– 8·50
Iroquois Indians			Gold	1·735	5– 8·28
Todas of the Nilghiries			Marshall	1·727	5– 7·95
Negroes of Calabar			Topinard	1·727	5– 7·95
North American Indians			Baxter	1·726	5– 7·93
Irish, all classes (recruits, 5 ft. 8·04)			Anthropometric Com.	1·725	5– 7·90
United States (whites, all classes)			Baxter	1·719	5– 7·67
English, all classes (recruits, 5 ft. 7·71)			Anthropometric Com.	1·719	5- 7·66
Norwegians		1·727	Beddoe	1·719	5- 7·66
	immigrants to U.S.	1·717	Baxter		
Zulus			Roberts	1·707	5– 7·19
English labouring classes			Anthropometric Com.	1·705	5– 7·08
Canadians, chiefly French immigrants, U.S. America			Baxter	1·703	5– 7·01
Tajiks of Ferghana and Samarkand			Ujfalvy	1·705	5– 7·10
Swedes, immigrants to U.S. America			Baxter and Beddoe	1·700	5– 6·90
Chipeway Indians			Oliver	1·700	5– 6·90
Kabyles, large race			Topinard	1·699	5– 6·85

TABLE VI. (*continued*).

Race or Nationality	Authority	Mètres	Ft. in.
Welsh, all classes	Anthropometric Com.	1·695	5– 6·66
Danes, immigrants to U.S. America	Baxter	1·694	5– 6·65
Dutch " "	Baxter	1·693	5– 6·62
American, negroes of all degrees of colour	Baxter	1·693	5– 6·62
English immigrants to U.S. America	Baxter	1·692	5– 6·58
Hungarians " "	Baxter	1·692	5– 6·58
English Jews	Anthropometric Com.	1·692	5– 6·57
Germans, immigrants to U.S. America	Baxter	1·691	5– 6·54
Swiss of Geneva	Dunant	1·688	5– 6·43
Swiss immigrants to U.S. America	Baxter	1·687	5– 6·38
Russians " "	Baxter	1·687	5– 6·38
Belgians	Quetelet	1·687	5– 6·38
French immigrants to U.S. America	Baxter	1·683	5– 6·23
Poles " "	Baxter	1·682	5– 6·20
French upper classes	De Quatrefages	1·681	5– 6·14
Germans	*Novara*	1·680	5– 6·10
Mexicans	Baxter	1·680	5– 6·10
Berbers of Algeria	Topinard	1·680	5– 6·10
Arabs	Various	1·679	5– 6·08
Usbeks of Ferghana and Samarkand	Ujfalvy	1·679	5– 6·08
Javanese	*Novara*	1·679	5– 6·08
Russians	Shultz	1·678	5– 6·04
Italians, immigrants to U.S. America	Baxter	1·677	5– 6·00
South Americans " "	Baxter	1·675	5– 5·90
Australian Aborigines	Various	1·669	5– 5·68
Austrian Sclaves	*Novara*	1·669	5– 5·68
Galchas, Iranian Mountaineers	Ujfalvy	1·668	5– 5·66
Spaniards, immigrants to U.S. America	Baxter	1·668	5– 5·66
Berbers of Algeria	Topinard	1·666	5– 5·62
Portuguese immigrants to U.S. America	Baxter	1·663	5– 5·43
Ainos	Rosky	1·660	5– 5·33
Austrian Germans	*Novara*	1·658	5– 5·27
French working classes	De Quatrefages	1·657	5– 5·24
Esquimaux of North America	Various	1·654	5– 5·10
Hungarians (military statistics)	Scheiber and Beddoe	1·652	5– 5·04
Caucasians	Shortt	1·650	5– 4·93
New Guinea, various tribes	Various	1·646	5– 4·78
Hindoos	Shortt	1·645	5– 4·76
Bavarians	*Novara*	1·643	5– 4·68
Ruthenians	Majer and Kopernicki	1·640	5– 4·54
Dravidians	Shortt	1·639	5– 4·50
Cingalese	Davy	1·638	5– 4·48
Austrian Roumanians	*Novara*	1·631	5– 4·37
Chinese	*Novara*	1·630	5– 4·17
Italians (conscripts, 1·620)	*An. di Statist.*, 1879	1·626	5– 4·00
Fuegans	*Novara*	1·625	5– 3·98
Polish Jews	Majer and Kopernicki	1·623	5– 3·88
Poles	Majer and Kopernicki	1·622	5– 3·87
Finns (Beddoe, 5 ft. 5·81)	*Novara*	1·617	5– 3·60
Papuans	Various	1·606	5– 3·20
Japanese	Mrs. Ayrton	1·604	5– 3·11
Aymaras Indians, Peru	Forbes	1·601	5– 3·00
Peruvians	D'Orbigny	1·600	5– 3·00
Cochin-Chinese	Finlayson	1·593	5– 2·70
Malays	Raffles, Crawfurd, &c.	1·583	5– 2·34
Veddas of Ceylon	Bailey	1·536	5– 0·42

Table VI. (*continued*).

Race or Nationality	Authority	Mètres	Ft. in.
Lapps	Horch	1·500	4– 11·2
Andamanese	Man	1·492	4– 10·7
Aëtas	De Quatrefages	1·482	4– 10·3
Semangs	De Quatrefages	1·448	4– 9·00
Mincopese	De Quatrefages	1·436	4– 8·53
Bosjesmans (Bushmen and S. Africa)	Various	1·341	4– 4·78
Difference between the tallest and shortest races		·421	1– 4·55
Average stature of man according to the above		1·658	5– 5·25

Special Subjects of Inquiry.

36. In the sheet of instructions issued by the Committee observations were asked for to illustrate the physical differences of:—

a. Persons engaged in different occupations.

b. Persons bred and living in towns, or country.

c. Natives of parts of the British Isles differing ethnologically, geologically, or in climate.

d. Boys and men whose intellect and industry are above or below the average.

e. The general characteristics of men noted for athletic power.

f. The rate of growth in persons of both sexes bred in town and country, and engaged in different occupations.

The following table shows some of the extreme variations in stature which occur, and which are associated with different occupations and conditions of life, illustrative of the above subjects of inquiry.

Table VII.—Showing the Stature and Weight of Adult Males (age 23–50 years) under different conditions of life.

	Number	Ft. in.	lbs.
Scotch Agricultural Population, Galloway	75	5 10·5	173·6
Metropolitan Police	192	5 10·1	185·7
Fellows of the Royal Society	98	5 9·76	—
Yorkshire Fishermen, Flambro'	68	5 8·71	166·8
Athletes (running, jumping, and walking)	89	5 8·34	143·7
Scotch Lead-miners, Wenlockhead	92	5 8·43	163·9
London Fire Brigade	69	5 7·40	160·8
Durham Coal-miners	51	5 6·38	152·4
Edinburgh and Glasgow Town Population	32	5 6·35	137·2
Welsh Lead-miners, Cardigan	328	5 6·30	155·2
Sheffield Town Population	100	5 5·80	142·5
Bristol Town Population	300	5 5·77	142·4
Lunatics, General Population	1,409	5 5·70	147·9
Criminals, General Population	2,315	5 5·60	140·4
Hertfordshire Labourers	174	5 5·35	145·0
Idiots and Imbeciles	19	5 4·87	123·0

37. The influence of town life and town occupations on the physique of the population in districts in which the race differs little, and the climatic

conditions are the same, is seen by comparing the agricultural population of Ayrshire with that of Glasgow and Edinburgh, where the average difference in stature amounts to 4·15 inches, and in weight to 36·4 lbs., in favour of the country folk. A similar, though not so great a difference, exists in Yorkshire, where the fishermen of Flamborough exceed the artisans of Sheffield in stature by 2·91 inches, and in weight by 24·3 lbs. On the other hand, the population of London exceeds that of the adjoining county of Hertfordshire in stature by 1·57 inches, and in weight by 7·9 lbs. Quetelet observed the same condition in Belgium, where the towns showed a higher stature than the country districts; and he concluded that the greater ease and better food attainable in towns were more favourable to physical development than the hard manual labour and poor fare of the agricultural districts. It is probable that Quetelet compared different classes together, or that the towns in Belgium hold an exceptional position, like London to the adjoining districts in England.

38. As an example of the predominance of race over occupation, the stature and weight of the Scotch lead-miners of Wenlockhead, and the Welsh lead-miners of Cardiganshire, are given in the table. The occupation of lead-mining in both districts is in a great measure hereditary, and has probably been followed under similar conditions in Scotland and Wales for many generations, yet the Scotch exceed the Welsh lead-miners in stature by 2·13 inches, and in weight by 8·7 lbs. The stature and weight of the Durham coal-miners, and of the town populations of Glasgow, Sheffield, and Bristol, are given in this table, as they have been referred to above as influencing the averages of their respective counties, and placing them in an exceptional position as to the racial origin of their inhabitants.

39. One of the objects the Committee has had in view has been 'to ascertain the physical differences of boys and men whose intellect and industry are above or below the average'; but no returns of this kind have been received, except some referring to criminals and lunatics, and those have been introduced here as the most convenient place for their consideration:—

Table VIII.—Showing the Stature and Weight of Adult Male Criminals and Lunatics, compared with that of the General Population.

Classes	Height				Weight			
	Ages				Ages			
	20 to 25	25 to 35	35 to 45	45 to 55	20 to 25	25 to 35	35 to 45	45 to 55
	inches	inches	inches	inches	lbs.	lbs.	lbs.	lbs.
General—								
Average population	67·5	67·9	67·9	67·9	146·2	156·	162·	163·8
Class 3: country labourers	67·2	67·5	67·5	67·8	149·5	157·4	161·2	166·4
Class 4: town artisans	66·5	66·6	66·9	66·6	139·	147·3	154·1	148·6
Criminals . . .	65·2	65·6	65·7	65·8	136·9	140·	141·4	143·4
Lunatics . . .	65·7				147·9			

40. When compared with the general population, lunatics show a deficiency of stature of 1·96 inches, and of weight 10·3 lbs.; and criminals of 2·06 inches and 17·8 lbs., indicating a deficiency of physical as well as mental stamina in both these unfortunate classes of society. In respect to complexion lunatics show an excess of 5 per cent. of light eyes with dark hair, and criminals of 10 per cent. of dark eyes with dark hair over the general population.

TABLE IX.—Showing the COMPLEXION of Adult Male Criminals and Lunatics, compared with that of the General Population.

	No. of observations	Eyes light			Eyes dark			Eyes light brown, green, or exceptional, with hair light or dark	Total
		Hair light	Hair dark	Hair red	Hair dark	Hair fair	Hair red		
		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	
England—									
General . .	5,669	39·6	20·4	4·0	29·9	1·7	·7	3·7	100
Criminal .	2,315	40·1	13·6	1·1	38·1	·6	·6	5·9	—
Lunatic . .	1,409	42·3	20·3	1·5	31·8	1·8	·4	1·9	—
Total . .	9,393	40·1	18·9	2·7	32·2	1·5	·6	4·	—
Wales—									
General . .	704	34·4	19·9	9·8	26·4	4·7	1·3	3·5	100
Criminal .	46	37·	17·4	—	45·6	—	—	—	—
Lunatic . .	150	34·7	27·3	3·3	28·7	2·	—	4·	—
Total . .	900	34·6	21·	8·2	27·8	4·	1·	3·4	—
Scotland—									
General . .	1,261	46·3	24·5	5·2	21·2	·9	1·	·9	100
Criminal .	194	44·3	20·1	2·6	30·	·5	1·5	1·	—
Lunatic . .	342	47·4	30·7	1·4	17·3	1·4	1·2	·6	—
Total . .	1,797	46·3	25·2	4·2	21·4	1·	1·1	·8	—
Ireland—									
General .	285	49·8	18·2	3·5	23·5	1·1	1·8	2·1	100
Criminal .	215	44·2	18·6	·5	28·7	·5	·5	7·	—
Lunatic .	29	51·7	24·1	7·	17·2	—	—	—	—
Total . .	529	47·4	19·	2·5	25·3	·7	1·1	4·	—
Total United Kingdom	12,619	41·	19·8	3·4	30·1	1·5	·7	3·5	—

41. As an example of the relation of high mental to physical qualities, the stature of ninety-eight Fellows of the Royal Society is given. Their average stature is slightly above (0·38 inch) that of the professional classes of this country, to which the majority of them belong.

42. As an example of high physical qualities as developed by training, the measurements of eighty-nine professional and amateur athletes are given. Their average stature exceeds that of the general population from which they are drawn by 0·68 inch, while their average weight falls short of that standard by 14·5 lbs. The ratio of weight to stature is, in the athletes, 2·100 lbs., and in the general population 2·323 lbs., for each inch of stature. Thus, a trained athlete whose stature is 5 feet 7 inches should weigh 10 stones, while an untrained man of the same height should weigh 11 stones.

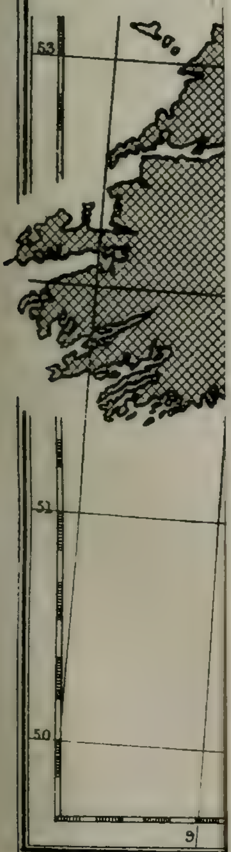
43. The statures of the Metropolitan Police and the London Fire Brigade are given as selected men of the working classes. The former exceed the criminal class, with whom they have to deal, in stature by 4·5 inches, and in weight by 45·3 lbs. The men of the Fire Brigade are selected for their activity, and general fitness to meet sudden and trying demands on their physical and mental energies. The data referring to them may be accepted, therefore, as typical of the best physique which can be obtained for an English army, and of which our army should consist at its best.

Complexion as determined by the Colour of the Eyes and Hair.

44. The difficulty of determining the prevailing complexion of a race, or of the mixed population of a country or a district, by the colour of the hair, as is generally done, and of basing a classification on it, is greater than at first sight appears. Not only do the various shades run imperceptibly into each other, but observers differ in their appreciation of the different shades when viewed under similar conditions, and the prevailing colour of a district determines the relative value of others. Thus a person living among a dark-haired race would consider brown hair as fair, while another person living among a light-haired people would consider it dark, or at any rate not fair in the same sense as the former would. Objections of this kind do not apply to the eyes, as the colour of the iris is due to the anatomical disposition of pigment in front of or behind that structure. In brown and the so-called black eyes a layer of brown pigment covers the *front* of the iris and hides the deeper structures, and itself determines the colour; while in blue and grey eyes this layer of pigment is wanting, and the colour is due to the dark pigment (the choroid) situated *behind* the iris, the blue colour in various degrees resulting from the greater translucency of a thin, and the grey from a thick membrane. The marriage, moreover, of fair and dark persons often produces an intermediate shade in the colour of the hair in the children, but only occasionally produces an intermediate change in the colour of the eyes, the rule being that they are blue or brown like one of the parents. The cross between the blue and brown eye should properly be called green (the deeper blue showing through an imperfect layer of yellow brown pigment), but from popular prejudice to this term, eyes of this mixed colour are generally recorded as brown grey, light brown or light hazel.[1]

45. For these reasons the classification adopted in this Report is based on the colour of the eyes, and with the object of more clearly defining the two prevailing shades of complexion in this country, namely the 'fair' as characterised by light eyes and light hair, and the 'dark' by dark eyes

[1] See the Report for 1880, p. 134, for a further discussion of this subject.



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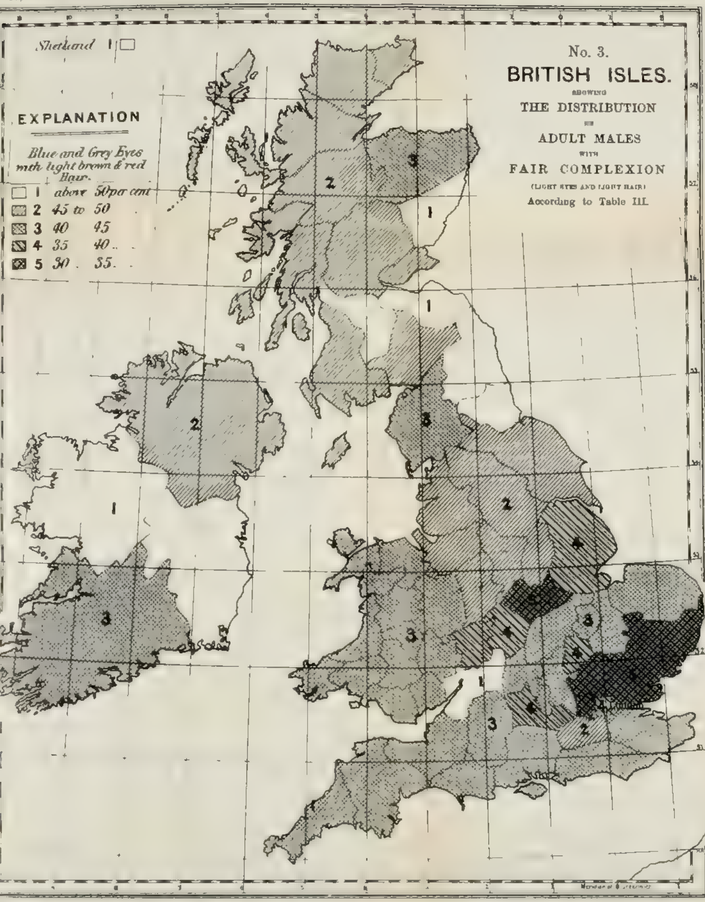
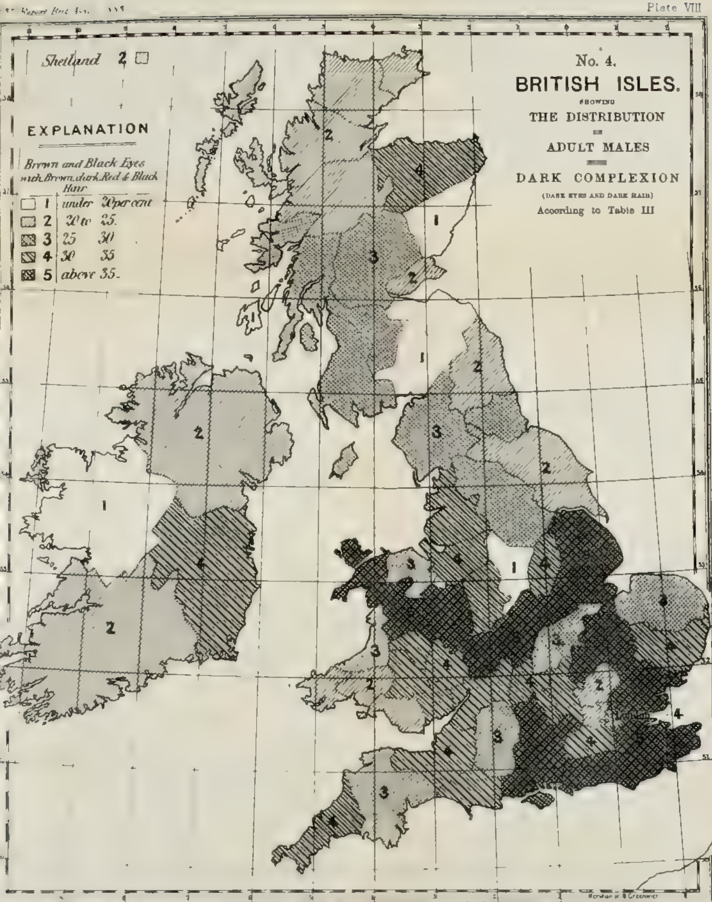


Illustrating the Report of the Anthropometric Committee



Illustrating the Report of the Anthropometric Committee

and dark hair, the mixed or neutral eyes are eliminated, and the dark hair is separated from the former, and the light hair from the latter class. The combinations of blue eyes and light red hair, and of brown eyes and dark red hair, are given in separate columns, but the result is not satisfactory, as many cases of light red have doubtless been returned as fair hair, and of dark red as dark brown hair.

46. In the instructions issued by the Committee observers were requested to return the colours of eyes as grey, light blue, blue, dark blue, light brown, brown, dark brown, green, and black; and the colour of the hair as very fair, fair, golden, red, red brown, light brown, brown, dark brown, black brown, and black, and some chromo-lithographic sheets as tests [1] for the colour of the hair were at first issued; but the system was found to be too complicated for ordinary observers to follow, and they were left to record the colours of both hair and eyes according to the popular meaning of the above terms. An examination of the returns shows that in many cases wide limits have been given to such words as fair, golden, and brown at one end of the scale, and of dark brown and black at the other, which has necessitated the concentration of the data to eliminate errors of observation, and what may be called the 'personal equation' of the colour-sense in different observers. In the Report of the Committee for 1880 a table is given of the colour of eyes and hair according to the above scale, of boys and men of the professional classes from ten to fifty years of age, but, apart from its including too wide a range of ages, it is not so well adapted for showing the relative prevalence of complexions as the one now given.

47. The following grouping of the counties according to the prevalence of fair complexion, or, what is the same thing, according to the degree of nigrescence, shows that certain large districts—much larger than the county boundaries—are occupied by inhabitants of similar racial origin, or who have been subject to conditions of life which have reduced them to similar shades of complexion. The division of the percentages into five degrees is, of course, quite arbitrary, and sometimes two counties, only divided from each other by a decimal, and belonging therefore to the same group, may be represented by a different number. The exact percentages are given in Table III.

48. In this classification the men with dark eyes and light hair are combined with those having neutral eyes (green) and light or dark hair, because they are few in number, and because this peculiar complexion is probably due to crossing of the light and dark stocks, and the persistence of one feature of the parent in the eyes and of the other in the hair. The fact that men with dark eyes and light hair are more frequently found in the south-western counties of England, where the light and dark races meet and overlap each other, supports this view of their mixed origin. This complexion, moreover, is common in childhood, but disappears as age advances. According to Table XI. it diminishes in males from 13 per cent., during the first five years of life to 1 per cent., at forty-five years of age, and in females from 16·4 per cent. to 2 per cent. during the same period.

[1] These test-sheets proved not to be well suited for the purpose for which they were intended. The colours were not well graduated, and did not possess the sheen or gloss of the natural hair, on which so much of the variation of the colour depends. On the subject of colour-scales, see the *Bulletins* of the Society of Anthropology of Paris, 3rd S. vi. pp. 91, 92.

TABLE X.—Classification of the Counties of Great Britain and the Provinces of Ireland according to the prevalence of FAIR COMPLEXION or the degree of NIGRESCENCE of Adult Males.

		Fair eyes, with fair hair No. per cent. 1 = above 50 2 = 45–50 3 = 40–45 4 = 35–40 5 = 30–35	Fair eyes, with dark hair No. per cent. 1 = 10 to 15 2 = 15 – 20 3 = 20 – 25 4 = 25 – 30 5 = 30 upwards	Dark eyes, with dark hair No. per cent. 1 under 20 2 = 20–25 3 = 25–30 4 = 30–35 5 = above 35	Degree of nigrescence	Neutral eyes, with light and dark hair No. per cent. 1 = 0 to 2 2 = 2 – 4 3 = 4 – 6 4 = 6 – 8 5 = 8 upwards
Norse	Shetland	1	1	2	4	1
English and Scotch East Border Group.	Forfar and Kincardine	1	4	1	6	1
	Lanark and Renfrew	1	2	3	6	1
	Edinburgh, Linlithgow, Haddington, and Berwick	1	4	1	6	2
	Dumfries, Roxburgh, Selkirk, and Peebles	2	5	1	8	1
	Northumberland	1	3	2	6	3
	Durham	1	2	3	6	2
Central Irish Group.	Connaught	1	3	1	5	1
	Leinster	1	1	4	6	3
North Irish Group	Ulster	2	3	2	7	2
Scotch Highland Group.	Sutherland, Ross, Cromarty, and Skye	2	4	2	8	1
	Inverness	2	4	2	8	1
	Perth, Stirling, and Dumbarton	2	3	3	8	1
	Argyle, Bute, and Arran	2	3	3	8	2
	Islay and Colonsay	2	5	1	8	1
	Kirkcudbright, Ayrshire, and Wigton	2	5	3	10	1
North-East Scotch Group.	Caithness	2	4	2	8	4
	Aberdeen, Banff, Elgin, and Nairn	3	3	4	10	2
	Fife, Kinross, and Clackmannan	2	4	2	8	3
North English Group.	North and East Ridings of Yorkshire	2	3	2	7	5
	West Riding of Yorkshire	2	2	3	7	2
	Nottinghamshire	2	2	4	8	1
	Cumberland and Westmoreland	3	4	3	10	2
	Lancashire	2	2	4	8	2
	Cheshire	2	2	4	8	2
	Derbyshire	2	4	1	7	3
	Staffordshire	2	2	4	8	2

English Fen Country Group.	Norfolk	3	3	3	9	4
	Cambridge and Huntingdonshire	3	1	5	9	1
	Northamptonshire	3	3	3	9	4
	Bedfordshire	4	1	5	10	3
South-west English Group.	Kent	3	1	5	9	3
	Sussex	3	2	5	10	3
	Surrey	2	2	4	8	2
	Oxfordshire and Buckingham	3	3	4	10	2
	Hampshire	3	2	5	10	3
	Wiltshire	3	4	3	10	1
	Gloucestershire (apparently exceptional)	1	1	4	6	2
	Dorsetshire	3	3	4	10	4
	Somersetshire	3	2	4	9	4
	Devonshire	3	3	3	9	3
	Cornwall	3	2	4	9	4
Welsh Group.	Denbigh and Flintshire	3	2	3	8	5
	Carnarvon, Anglesea, Merioneth, and Montgomery	3	1	5	9	3
	Cardiganshire	3	3	3	9	2
	Brecon and Radnor	3	3	4	10	1
	Glamorgan, Caermarthen, and Pembroke	3	3	2	8	5
	Shropshire	3	2	5	10	2
	Hereford and Monmouth	3	3	4	10	3
South-west Irish Group.	Munster	3	3	2	8	5
Mid-English Group.	Lincolnshire	4	3	5	12	2
	Leicester and Rutlandshire	5	2	5	12	3
	Warwickshire	4	2	5	11	3
	Worcestershire	4	2	5	11	1
London and Home Counties Group.	London	4	2	4	10	5
	Berkshire	4	2	5	11	4
	Hertfordshire and Middlesex	5	5	2	12	5
	Suffolk	5	3	4	12	5
	Essex	5	4	5	14	4

TABLE XI.—Showing the COLOUR of EYES and HAIR of both

Males.

Age last birthday	Number of observations	Eyes light — Light blue, blue, dark blue, light grey, grey, dark grey — Hair: Very fair, fair, light brown, brown	Eyes light — Hair: Dark brown, black brown, black	Eyes light — Hair: Golden, red	Eyes neutral — Green, brown-grey, light brown — Hair: Very fair, fair, red, brown, black	Eyes dark — Brown, hazel, dark brown, black — Hair: Brown, dark brown, black brown, black	Eyes dark — Hair: Very fair, fair, light brown	Eyes dark — Hair: Red, auburn, red brown	Eyes: Light—Blue to grey	Eyes: Mixed—Green to light brown	Eyes: Dark—Brown to black	Hair: Light—Fair to brown	Hair: Red—Light to dark	Hair: Dark—Brown to black
		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.			per cent.		
Birth	40	100	—	—	—	—	—	—	100	—	—	—	—	—
½	29	62	—	—	24	—	14	—	62	24	14	76	—	—
1	5	60	20	—	20	—	—	—	80	20	—	60	—	20
2	3	— } 56·0	— } 9·3	— } 7·5	— } 15·0	— } 15·5	— } 13·0	— } 1·5	100	—	—	100	—	—
3	64	50	6	8	12	16	6	2	64	12	24	56	10	22
4	101	52	2	7	4	15	19	1	61	4	35	71	8	17
5	197	52	5	7	7	16	12	1	64	7	29	64	8	21
6	222	51	5	4	13	19	7	1	60	13	27	58	5	24
7	265	51 } 51·4	5 } 5·6	5 } 4·6	14 } 10·8	17 } 19·2	7 } 7·4	1 } 1·0	61	14	25	58	6	22
8	270	47	6	5	13	22	6	1	58	13	29	53	6	28
9	340	56	7	2	7	22	5	1	65	7	28	61	3	29
10	251	52	12	2	4	24	3	3	66	4	30	55	5	36
11	265	54	11	5	4	20	5	1	70	4	26	59	6	31
12	352	50 } 51·2	14 } 12·8	2 } 3·2	11 } 6·2	20 } 21·4	2 } 3·6	1 } 1·6	66	11	23	52	3	34
13	464	48	12	4	6	23	5	2	64	6	30	53	6	35
14	378	52	15	3	6	20	3	1	70	6	24	55	4	35
15	253	53	14	3	10	17	2	1	70	10	20	55	4	31
16	278	43	17	5	11	20	3	1	65	11	24	46	6	37
17	345	40 } 43·8	14 } 14·2	4 } 4·2	12 } 11·2	25 } 22·6	4 } 3·2	1 } 0·8	58	12	30	44	5	39
18	448	44	13	3	11	26	3	—	60	11	29	47	3	39
19	454	39	13	6	12	25	4	1	58	12	30	43	7	38
20	331	42	14	6	8	26	3	1	62	8	30	45	7	40
21	281	48	18	3	6	22	2	1	69	6	25	50	4	40
22	257	39 } 42·2	15 } 16·4	3 } 3·2	9 } 8·6	32 } 27·0	1 } 1·8	1 } 0·8	57	9	34	40	4	47
23	261	43	17	2	9	26	2	1	62	9	29	45	3	43
24	236	39	18	2	11	29	1	—	59	11	30	40	2	47
25	199	41	17	5	7	27	3	—	63	7	30	44	5	44
26	183	36	20	4	6	33	1	—	60	6	34	37	4	53
27	189	34 } 32·8	20 } 20·8	2 } 4·2	8 } 7·0	30 } 32·0	3 } 2·0	3 } 1·2	56	8	36	37	5	50
28	179	28	27	3	5	34	2	1	58	5	37	30	4	61
29	150	25	20	7	9	36	1	2	52	9	39	26	9	56
30–40	900	34	26	5	6	26	2	1	65	6	29	36	6	52
40–50	392	33	34	6	6	20	1	—	73	6	21	34	6	54
50–60	85	36	22	13	7	20	1	1	71	7	22	37	14	42
60–70	32	53	19	6	3	19	—	—	78	3	19	53	6	38
70–														

Sexes at all Ages of English and Welsh Origin.

Females.

Age last birthday	Number of observations	Eyes light (Light blue, blue, dark blue, light grey, grey, dark grey) — Hair: Very fair, fair, light brown, brown	(group)	Eyes light — Hair: Dark brown, black brown, black	(group)	Eyes light — Hair: Golden, red	(group)	Eyes neutral (Green, brown-grey, light brown) — Hair: Very fair, fair, red, brown, black	(group)	Eyes dark (Brown, hazel, dark brown, black) — Hair: Brown, dark brown, black brown, black	(group)	Eyes dark — Hair: Very fair, fair, light brown	(group)	Eyes dark — Hair: Red, auburn, red brown	(group)	Eyes: Light—Blue to grey	Eyes: Mixed—Green to light-brown	Eyes: Dark—Brown to black	Hair: Light—Fair to brown	Hair: Red—Light to dark	Hair: Dark—Brown to black
		per cent.		per cent.		per cent.		per cent.		per cent.		per cent.		per cent.		per cent.			per cent.		
Birth	36	100		—		—		—		—		—		—		100	—	—	—	—	—
½	34	59		6		—		20		3		12		—		65	20	15	71	—	9
1	11	46		—		—		—		36		18		—		46	—	54	64	—	36
2	15	47	47·8	—	7·3	—	—	—	—	33	21·4	13	16·4	7	4·0	47	—	53	60	7	33
3	45	47		7		—		4		18		22		2		54	4	42	69	2	25
4	119	40		9		9		5		17		17		3		58	5	37	57	12	26
5	192	53		7		3		9		19		8		1		63	9	28	61	4	26
6	229	51		10		5		9		17		5		3		66	9	25	56	8	27
7	223	53	52·6	9	8·8	3	3·4	9	7·6	16	20·2	8	5·6	2	1·3	65	9	26	61	5	25
8	178	53		12		3		7		21		3		1		68	7	25	56	4	33
9	237	53		6		3		4		28		4		2		62	4	34	57	5	34
10	281	60		8		4		2		22		3		1		72	2	26	63	5	30
11	322	52		11		4		4		22		5		2		67	4	29	57	6	33
12	298	47	51·0	15	10·8	3	3·8	6	5·6	25	23·8	1	3·2	3	1·8	65	6	29	48	6	40
13	251	47		10		5		6		27		4		1		62	6	32	51	6	37
14	265	49		10		3		10		23		3		2		62	10	28	52	5	33
15	167	45		12		1		9		27		4		2		58	9	33	49	3	39
16	110	52		17		1		5		20		4		1		70	5	25	56	2	37
17	47	55	47·0	17	15·0	—	—	7	7·8	17	23·8	4	4·4	—	1·3	72	7	21	59	—	34
18	64	37		15		—		9		31		8		—		52	9	39	45	—	46
19	94	46		14		4		9		24		2		1		64	9	27	48	5	38
20	125	46		10		3		10		25		5		1		59	10	31	51	4	35
21	60	38		17		3		10		30		—		2		58	10	32	38	5	47
22	53	51	45·0	15	13·0	2	3·2	9	11·8	19	24·0	4	4·0	—	1·5	68	9	23	55	2	34
23	31	45		13		3		10		26		3		—		61	10	29	48	3	39
24	20	45		10		5		20		20		—		—		60	20	20	45	5	30
25, 26, 27, 28, 29	46	38		15		2		8		31		2		4		55	8	37	40	6	46
30–40	27	44		12		3		11		30		—		—		59	11	30	44	3	42
40–50, 50–60, 60–70, 70–	20	30		20		15		10		25		—		—		65	10	25	30	15	45

49. In connection with this subject Table XI., showing the colour of eyes and hair in both sexes and at all ages, should be studied, as it shows the comparative worthlessness of the method often resorted to on the Continent of determining the racial elements of a country by examining the complexion of school children of different ages. The first column, referring to males (light eyes and fair hair), shows the gradual darkening of the hair of fair-complexioned children from 56 per cent. at the first five years of life to 33 per cent. at forty-five years; and the second column (light eyes with dark hair) increases during the same period at nearly a corresponding rate, the percentage of dark hair being 9·3 in the first five years and 34 at forty-five years of age. Thus, $56 + 9{\cdot}3 = 65{\cdot}3$, and $33 + 34 = 67$, or only 1·7 per cent. excess of dark hair received from other sources, or due to probable error of observation. In like manner the green and light-brown eyes of the middle column of the table decrease in number, or in other words become darker, and are transferred to the next column (dark eyes and dark hair) as age advances, from 15 per cent. at the first five years to 6 per cent. at forty-five years of age. The fifth column (dark eyes and hair) increases at the expense of the two adjoining columns from 15·5 per cent. at three and four years to 36 per cent. at twenty-nine years, after which age the percentage falls off very rapidly on account of the earlier accession of grey hair in the dark than the fair complexion of the first column, to which the higher percentages become transferred. The low percentage of dark complexion at ages from forty to seventy years does not arise from the elimination of this complexion by advancing age, or by death, but from the fault of the observers not having recorded the original colour of the hair before it became grey, which necessitated the rejection of all such returns in drawing up the table.

50. The table referring to females shows that darkening of the hair and eyes takes place to a much less extent amongst them than among males, and that there is little disposition for the dark hair to turn grey with advancing age. For corresponding periods to those applied to males, the fair-complexioned females in the first column lose 3·8 per cent. of their number, while the second column receives an accession of dark hair of 4·7 per cent. The dark-complexioned (dark eyes and hair) females in the fifth column increase by 8·6 per cent., at the sole expense of the sixth column, by the darkening of the hair. Unlike the males, the column showing the neutral eyes somewhat increases instead of decreases; and this increase appears to have come from the column containing the fair eyes and red hair, or it may be attributed to the difference in the 'colour equation' of some of the observers—women being much more critical, and therefore less consistent, than men in the definition of colours.

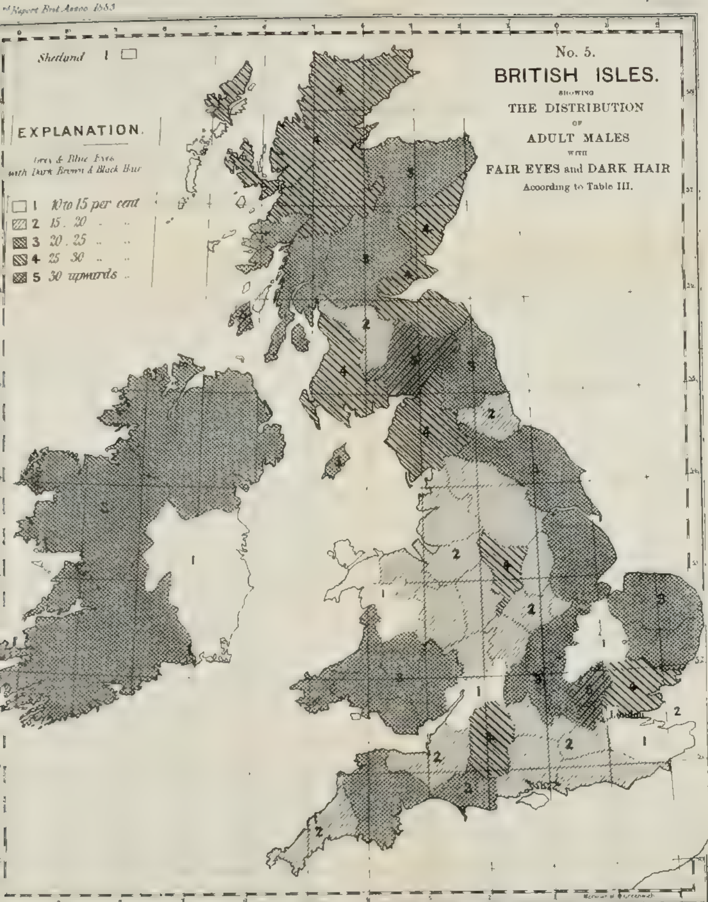
NOTE.—Dr. Beddoe proposes the use of indices of nigrescence for the classification of the colour of hair and eyes. 'That for the hair is got by subtracting the fair and the red from the dark hair plus twice the black, leaving out the neutral browns, thus:—

2 Black (N) + Dk. Br. − Fair − Red = Index.

The black hair is doubled, because its occurrence shows a much greater tendency to melanosity. The index for the eyes is got by subtracting the light from the dark and neglecting the neutral shades, thus:—

Dark − Light = Index.'

C. Roberts



Illustrating the Report of the Anthropometric Committee

Children and Adults of both Sexes.

51. A large portion of the statistics collected by the Committee refer to children, and these, together with those referring to the adults already considered in the early part of this Report, have been arranged in Tables XV. to XXV. to show the influence of age, sex, nurture, occupation, and sanitary surroundings on the physical development of the British population. The children are chiefly those of English parents, as few returns have been received from other parts of the kingdom. All classes of the community are represented, from the upper and professional classes whose children attend the Public Schools, like Eton, Marlborough, and Radley, to the poorest town population, whose children are found in the public elementary (or Board) schools, charitable institutions, and industrial schools. The adults also include all classes, from the Universities of Oxford and Cambridge, to town labourers and factory operatives.

52. In deciding upon the arrangement for practical purposes of returns so varied in their origin, and yet consisting in so large a proportion of information derived from special sources, the first consideration has been to establish a classification of the returns according to the *media*, or influences which have been instrumental in differentiating one class from another. The Committee has adopted the subjoined scheme, prepared by Mr. Roberts, and first brought before the Association in a paper read in the Anthropological Section in 1878. It is based on the principle of collecting into a standard class as large a number of cases as possible which imply the most favourable conditions of existence in respect to fresh air, exercise, and wholesome and sufficient food—in one word, nurture—and specialising into classes which may be compared with this standard those which depart more or less from the most favourable condition. By this means, in respect to social condition, the influence of mental and manual work; in respect to nurture, the influence of food, clothing, &c., on development; in respect to occupation, the influence of physical conditions; and in respect to climate and sanitary conditions, the influence of town and country life may be determined.

53. The classification has been constructed on the physiological and hygienic laws which are familiar to the students of sanitary science, and on a careful comparison of the measurements of different classes of the people, and especially of school children of the age of from eleven to twelve years. This age has been selected as particularly suited to the study of the *media*, or conditions of life, which influence the development of the human body, as it is subject to all the wide and more powerful agencies which surround and divide class from class, but is yet free from the disturbing elements of puberty and the numerous minor modifying influences, such as occupation, personal habits, &c., which in a measure shape the physique of older boys and adults. The data on which the classification has been based are given below. The most obvious facts which the figures disclose are the check which growth receives as we descend lower and lower in the social scale, and that a difference of five inches exists between the average statures of the best and the worst nurtured classes of children of corresponding ages, and of 3½ inches in adults.

TABLE XII.—Classification of the British Population according to *Media*—Occupation and other conditions of life.

*Social Condition.**—Non-labouring Classes.			Labouring Classes			
Nurture.†—Very Good		Good	Imperfect		Bad	
Professional Classes ‡ (Upper and Upper Middle Classes) 4·46 per cent.		Commercial Class (Lower Mid. Classes) 10·36 per cent.	Labourers 47·46 per cent.	Artisans 26·82 per cent.	Industrial Classes (Sedentary Trades) 10·90 per cent.	Selected Classes
Out-door § Country	In-door Towns	In-door Towns	Out-door Country	In-door Towns	In-door Towns	
CLASS I. Country-gentlemen. Gentlemen-farmers. Officers of Army and Navy. Auxiliary Forces. Clergymen. Lawyers. Doctors. Civil Engineers. Architects. Dentists.	Civil Servants. Authors. Artists. Teachers. Musicians. Actors. Bankers. Merchants (Wholesale).	CLASS II. Teachers in Elementary Schools. Clerks. Shopkeepers. Shopmen. Dealers in „ Drugs. „ Books. „ Wool. „ Silk. „ Cotton. „ Foods. „ Drinks. „ Furniture. „ Metals. „ Glass. „ Earthenware. „ Fuel, &c.	CLASS III. Labourers and Workers on Agriculture. „ Gardens. „ Roads. „ Railways. „ Quarries. Navvies. Porters. Guards. Woodmen. Brickmakers. Labourers, &c., on Water. „ Sailors. „ Fishermen. „ Watermen. Labourers, &c., in Mines. „ Coal. „ Minerals.	CLASS IV. Workers in „ Wood. „ Metal. „ Stone. „ Leather. „ Paper. &c. Engravers. Photographers. Printers. &c.	CLASS V. Factory Operatives. Tailors. Shoemakers. &c.	CLASS VI. Policemen. Fire Brigade. Soldiers. Recruits. Lunatics. Criminals. Industrial-schools.

* Social Condition; (influences of leisure, mental and manual labour).
† Nurture; (influences of food, clothing, nursing, domestic surroundings, &c.)
‡ Occupation; (influences of external physical conditions, exercise, &c.) Percentage of male population, including male children (Census of 1871).
§ Climatic and sanitary surroundings.

TABLE XIII.—Table showing the RELATIVE STATURES of BOYS of the age of 11 to 12 years, under different social and physical conditions of life. The zigzag line running through the *means* shows the degradation of stature as the boys are further and further removed from the most favourable conditions of growth.

Height in inches	Total No. of Observations	Public Schools	Middle-class Schools		Elementary Schools				Military Asylums	Industrial Schools
		Country	Upper — Towns	Lower — Towns	Agricultural Labourers — Country	Artisans — Towns	Factories and Work-shops: Country	Factories and Work-shops: Towns		
60–	6	2	—	3	—	1	—	—	—	—
59–	16	2	3	5	2	2	—	—	1	—
58–	35	9	9	8	5	0	2	—	2	—
57–	66	11	17	13	4	4	5	5	7	1
56–	118	21	23	27	14	4	10	3	15	—
55–	230	28	35	57	32	15	13	17	33	—
54–	329	33	53	68	47	24	36	20	46	2
53–	361	15	55	58	47	26	34	38	84	4
Mean 52–	441	14	37	61	58	36	52	59	118	6
51–	370	6	25	40	36	28	45	57	123	10
50–	367	7	23	27	32	17	46	61	143	11
49–	252	2	8	20	14	12	31	40	114	11
48–	132	—	3	1	7	4	11	20	76	10
47–	102	—	3	4	5	7	5	13	59	6
46–	22	—	—	—	1	1	3	7	7	3
45–	12	—	—	—	—	—	—	1	10	1
44–	1	—	—	—	—	—	—	—	0	1
43–	1	—	—	—	—	—	—	—	1	—
42–	1	—	—	—	—	—	—	—	1	—
Total	2862	150	294	392	304	181	293	341	840	66
Average hgt.	52·60	54·98	53·85	53·70	53·01	52·60	52·17	51·56	51·20	50·02
Mean height	52·5	55·0	54·0	53·5	53·0	52·5	52·0	51·5	51·0	50·0

TABLE XIV.—Showing the RELATIVE STATURE of ADULTS of the ages from 25 to 30 years under different social and physical conditions of life.

The horizontal black lines show the *mean* Height of each class and the degradation from the standard class.

Height in inches	General Population, all Classes	Class I. Professional Classes	Class II. Commercial Classes, Clerks and Shopkeepers	Class III. Labouring Classes, Agriculturl. Miners, Sailors	Class IV. Artisan Classes living in Towns	Class V. Sedentary Occupations: Factories, Tailors	Class VI.—Special Classes: Prisoners, all Classes	Class VI.—Special Classes: Lunatics, all Classes
76–	—	—	—	—	—	—	—	—
75–	1	—	—	1	—	—	—	—
74–	7	1	—	6	—	—	1	—
73–	19	3	2	11	2	1	2	1
72–	39	7	6	24	2	—	3	2
71–	66	9	8	42	3	4	6	6
70–	114	21	14	56	14	9	20	7
69–	176	20	30	103	15	8	29	18
68–	222	13	25	130	41	13	41	20
67–	309	16	35	179	57	22	73	40
66–	282	8	24	144	78	28	78	62
65–	241	4	19	111	64	43	76	51
64–	151	2	11	69	38	31	78	52
63–	74	2	5	38	17	12	41	29
62–	39	—	1	20	4	14	21	29
61–	15	1	—	6	5	3	17	12
60–	4	—	—	1	2	1	2	5
59–	6	—	—	2	—	4	1	4
58–	1	—	—	1	—	—	1	1
57–	1	—	—	1	—	—	—	2
56–	—	—	—	—	—	—	1	—
Total	1935	107	180	945	342	193	491	341
Mean Height . .	67·5	69·0	68·0	67·5	66·5	65·5	66·0	65·5
Average	67·43	69·14	67·95	67·51	66·61	65·92	66·16	65·65
Average . . .	67·21	Calculated from the percentage portion of the five classes in the general population.						

Infants at Birth. Table XV.

54. The statistics relating to infants at birth have been tabulated separately, because the conditions of measurement differ from those of other children, the stature having been taken in the recumbent position, and the weight without clothing. The parents of the infants were English and Scotch; and although the charitable institutions from which the observations were obtained are situated in London and Edinburgh, persons bred in the country are frequently admitted as inmates, and it is probable, therefore, that the statistics fairly represent the labouring classes. Observations on infants of other classes of society could not be obtained. The statistics refer only to infants presumably born at the full period of gestation, and contain the due proportion of twin births. The table is constructed to show the relative stature and weight of each infant, and the differences between the sexes.

55. The table is one of great interest to the student examining the physical development and the physical improvement of a race, as it presents the materials with which he has to deal in its earliest and simplest form. According to this table the average length of male infants is 19·52 inches, and of females 19·32 inches, showing a difference of only one-fifth of an inch. The average naked weight of male infants is 7·12 lbs., and of females 6·94 lbs., a difference of about 3 ounces in favour of males. The range of height between the tallest and shortest male infants is 10 inches, while that of boys of 15 years, when the disturbing influences of puberty are present, is 27 inches. This wide range in adolescence becomes contracted in adults to 20 inches. The range of height of female infants is two inches less than that of male infants, which may be due to accidental causes, but which suggests a less disposition to variation in the size in females than in males,[1] and which may be the cause of the greater freedom of female infants from accidents at the time of birth. It has been ascertained that still births occur in this country in the proportion of 140 males to 100 females, and this higher death-rate of male infants has been attributed to their greater size. We have no statistics of the size or weight of still-born infants, although they could be more easily obtained than those of living infants, but the table before us would seem to confirm this view, as the largest surviving infants are those of males. It would appear, therefore, that the physical (and most probably the mental) proportions of a race, and their uniformity within certain limits, are largely dependent on the size of the female pelvis, which acts as a gauge, as it were, of the race, and eliminates the largest infants, especially those with large heads (and presumably more brains), by preventing their survival at birth.[2]

[1] The greater disposition to vary in range of stature of males than females has been already referred to in the Report of the Committee for 1880, p. 141, in connection with Sir Rawson Rawson's analysis of the successive annual measurements of 12 boys and 13 girls made by Professor Bowditch, of Harvard, United States. 'A marked feature in the charts when compared together is the greater regularity and parallelism of the growth of the girls, especially at the earlier periods of life.'

[2] To ascertain if there is any difference between the circumference of the skull as compared with that of the pelvis in adults of very different races of man, Mr. Roberts has measured the skulls and pelves of some European and Andamanese

TABLE XV.—Showing the HEIGHT (LENGTH) and WEIGHT of Infants of both Sexes at Birth.

Height, nearest inch	Weight in lbs. (naked) 3½		4½		5½		6½		7½		8½		9½		10½		11½		Total at each height		Average weight		Ratio, Weight ÷ Height	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
24 . .	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	9·5	—	·354	—
23 . .	—	—	—	—	—	—	—	—	1	1	2	3	2	—	1	—	—	—	6	4	9·0	8·2	·391	·356
22 . .	—	—	—	—	—	—	1	3	4	3	8	11	6	2	—	—	1	—	20	19	8·5	8·1	·386	·368
21 . .	—	—	—	—	—	—	11	10	40	38	21	6	1	5	2	1	—	—	75	60	7·7	7·7	·366	·366
20 . .	—	—	—	—	5	8	32	38	69	50	25	16	2	5	—	—	—	—	133	117	7·4	7·3	·370	·366
19 . .	—	—	1	—	17	17	45	64	44	36	7	12	2	2	—	—	—	—	116	131	6·9	6·9	·363	·363
18 . .	—	—	1	7	18	30	41	47	10	23	3	2	—	—	—	—	—	—	73	109	6·4	6·3	·355	·350
17 . .	—	—	3	6	13	10	3	6	—	3	—	—	—	—	—	—	—	—	19	25	5·5	5·7	·323	·335
16 . .	—	—	4	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	6	1	5·0	5·5	·312	·344
15 . .	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	3·5	—	·233	—
Total at each weight .	2	—	9	13	55	66	133	168	168	154	66	50	14	14	3	1	1	—	451	466	7·1	6·9	—	—
Average height . .	15·0	—	17·0	17·5	18·2	18·3	19·0	19·0	19·8	19·7	20·5	20·4	21·5	20·5	21·7	21·0	22·0	—	19·52	19·32	—	—	—	—
Ratio, Height ÷ Weight	4·28	—	3·77	3·88	3·31	3·32	2·92	2·92	2·64	2·62	2·44	2·45	2·26	2·16	2·06	—	—	—	—	—	—	—	—	—

NOTE.—According to this table, the average difference in the length and weight of the two sexes at birth is $\frac{1}{5}$th of an inch and $\frac{1}{5}$th of a pound in favour of males; but as the table contains 1 female and 8 males below 17 inches and 5 lbs., it is probable that the average for females is a little too high. On the other hand, one male is returned as 24 inches long and another as weighing 11 lbs., but there are no females of corresponding size. The statistics were obtained from the Queen Charlotte's Lying-in Hospital, London, and from the Royal Maternity Charity, Edinburgh.

Growth of Children of both Sexes.

56. Tables XVI. to XXII. show the growth of children of four of the five classes into which the returns have been divided. Class I. comprises the upper and professional classes and their children, and it may be accepted as representing the best physique of this country, and used as a standard with which to compare all other classes. According to the census of 1871 this class constitutes 4·46 per cent. of the population. Class II. consists of the commercial classes, such as clerks and shopkeepers and their children, whose occupations are carried on in towns, and for the most part indoors, and therefore under less favourable conditions to healthy development than the constituents of Class I. Class II. comprises 10·36 per cent. of the population. Class III. represents the labouring classes, such as agricultural labourers, fishermen, miners, and others who follow outdoor healthy occupations, but whose nurture is inferior to the two former classes. This class comprises 47·46 per cent. or nearly half the population of the country. Class IV. represents the mass of our town population engaged as artisans. Their trades, being carried on indoors, and requiring less physical exercise than Class III., place them under less favourable conditions as to sanitary surroundings. This class forms 26·82 per cent., or about a fourth of the population. Class V., comprising persons living in towns and following sedentary occupations under the most unfavourable conditions as to nurture and sanitary surroundings, has been omitted from the tables, as sufficient data have not been received to fairly represent it. This class constitutes 10·90 per cent. of the population.

57. The average stature and weight of each of the four classes have been worked out from the number of observations for each class, but as the several classes constitute different proportions of the general population the average representing the 'general population' has not been worked out from the total number of observations, but is the average of

skeletons in the Museum of the Royal College of Surgeons, with the following results:—

	Stature. Metres.	Average circumference of Pelvis. m.m.		Average circumference of Head. m.m.	Ratio of Pelvis to Head.
1 European female	1·592	430		500	1 to 1·16
6 European males	1·712	410		530	1–1·29
Female pelvis		430	Male head	530	1–1·23
10 Andamanese females	1·408	348		462	1–1·33
7 Andamanese males	1·492	337		477	1–1·42
Female pelvis		348	Male head	477	1–1·37

Only one European female skeleton was available for these measurements, but it appeared to be in every respect a normal one.

From these measurements it is obvious that the difference between the circumference of the head and the pelvis in the adult is much less in the large European than in the small Andaman race, and it is not improbable that the relatively small pelvis of the female Andamanese has been instrumental, in some measure, in differentiating that diminutive race. It is probably in this direction we must look for an explanation of the degenerating influences of town life and sedentary occupations, as they, together with the new movement for the higher education of women, favour the productions of large heads and imperfectly developed bodies of women in this and other civilised countries, and a corresponding disproportion between the size of the head and the circumference of the pelvis.

the other four averages, and it is therefore the average of the four classes rather than of all the individuals measured and weighed. The observations referring to adults are fairly representative of the general population as they were received from all parts of the country; but those referring to children were received from schools devoted to the education of special classes of society, and in numbers which did not correspond with their respective percentage proportion of the general population. By adopting the average of the averages of the four classes into which the school children have been distributed according to the occupations of their parents, the inequality of the percentage proportion has been eliminated. Tables and a diagram showing the *mean* stature, weight, chest-girth, and strength of males, as deduced from all the observations collected by the Committee, are given in the Report of 1881.

58. Tables (XIII., XIV.) have already been given (s. 53) which show the falling off in the average stature of children of the age 11–12 years, and of adults of the age 25–30 years, as the conditions under which they live are less and less favourable to healthy physical development. The children vary to the extent of five inches, and the adults to $3\frac{1}{2}$ inches, and corresponding variations occur in the weights and other physical qualities.

59. Plate X. shows the growth in stature, weight, and strength of individuals of both sexes, and the girth of chest, head, arm, and leg of males as far as they have been recorded in the returns received by the committee. The tracings are made from the *averages* in the column representing the general population. Similar tracings of the standard class (males) having been given in the Report for 1880.

60. An examination of the curves and tables shows the following facts:—

(1) Growth is most rapid during the first five years of life; the observations, however, at those ages are not sufficient in number or variety to give a trustworthy average.

(2) From birth to the age of five years the rate of growth is the same in both sexes, girls being a little shorter in stature and lighter in weight than boys.

(3) From 5 to 10 years boys grow a little more rapidly than girls, the difference being apparently due to a check in the growth of girls at these ages.

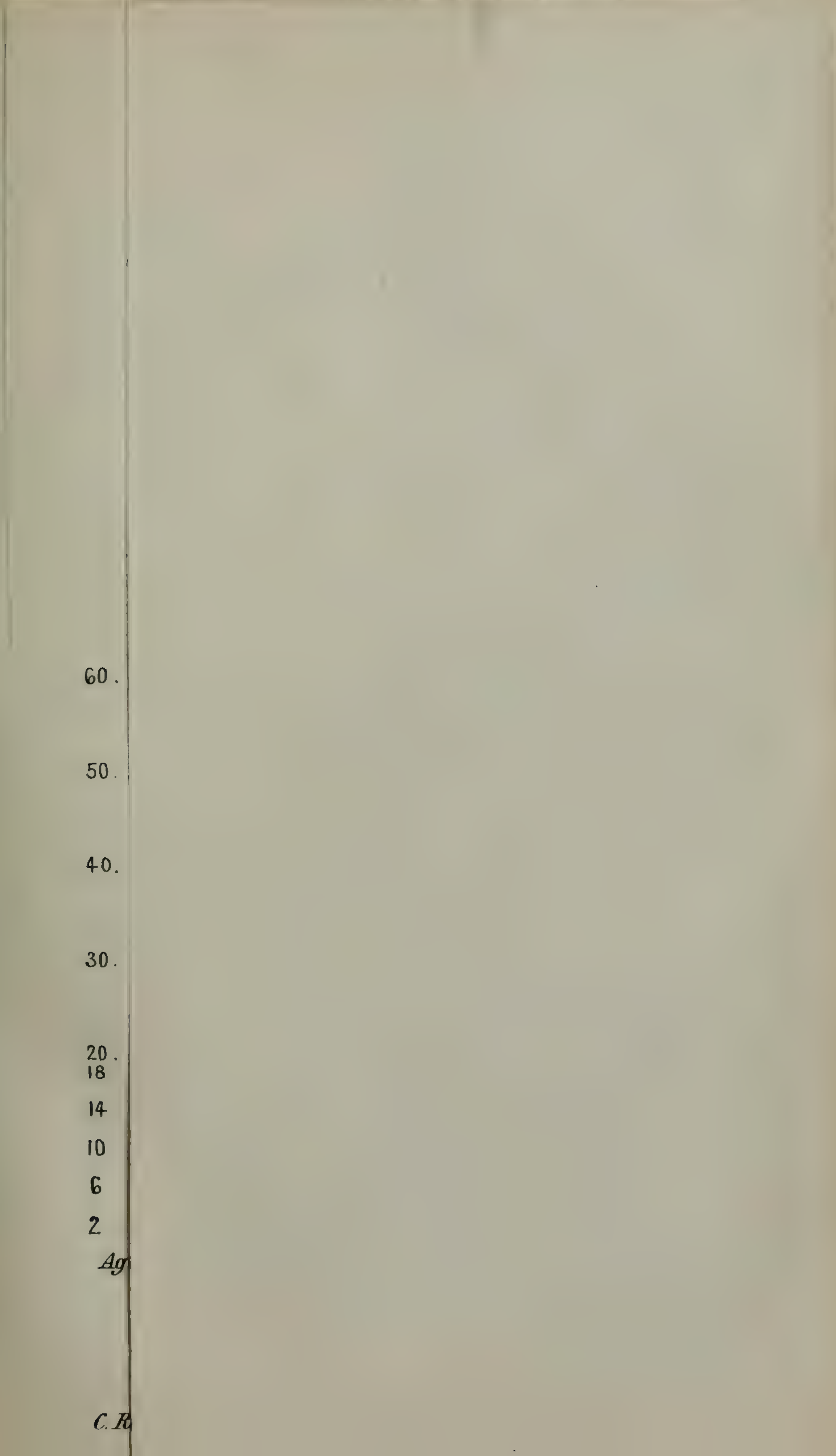
(4) From 10 to 15 years girls grow more rapidly than boys, and at the ages $11\frac{1}{2}$ to $14\frac{1}{2}$ are actually taller, and from $12\frac{1}{2}$ to $15\frac{1}{2}$ years actually heavier than boys. This difference appears to be due to a check in the growth of boys as well as an acceleration in the growth of girls incident on the accession of puberty.

(5) From 15 to 20 years boys again take the lead, and grow at first rapidly, and gradually slower, and complete their growth at about 23 years. After 15, girls grow very slowly, and attain their full stature about the 20th year.

(6) The tracings and tables show a slow but steady increase in stature up to the 50th year, and a more rapid increase in weight up to the 60th year in males, but the statistics of females are too few after the age of 23 to determine the stature and weight of that sex at the more advanced periods of life.

(7) The curve of the chest-girth in males shows an increase at a rate similar to that of the weight up to the age of 50 years, but it appears to have no definite relation to the curve of stature.

(8) The strength of males increases rapidly from 12 to 19 years, and


60.
50.
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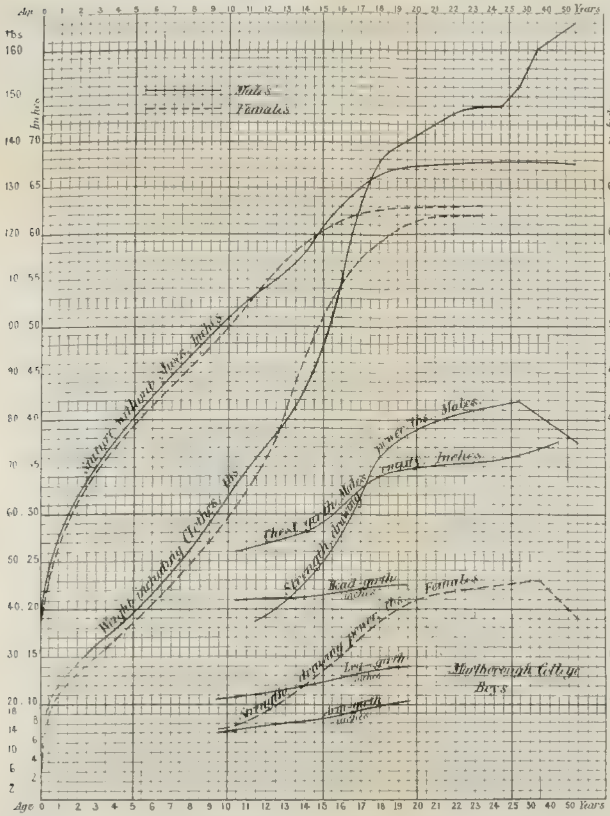
2

Diagram showing the Stature, Weight, Chest girth and Strength of both Sexes, at all Ages of the General Population of the United Kingdom



Illustrating the Report of the Anthropometric Committee.

C. Roberts

Spottiswoode & Co. Lith. London

at a rate similar to that of the weight; more slowly and regularly up to 30 years, after which it declines at an increasing rate to the age of 60 years. The strength of females increases at a more uniform rate from 9 to 19 years, more slowly to 30, after which it falls off in a manner similar to that of males. The curves of strength for the two sexes are not parallel: at 11 years females are weaker than males by 22 lbs., at 20 years of age by 36 lbs.

The Period of Maturity in Man.

61. The Tables do not show distinctly at what period man attains his full stature, and much difference of opinion exists on this subject. Some French writers (Barnard, Allaire, &c.) maintain that growth in height goes on until the 32nd or 35th year, and Dr. Baxter arrives at the same conclusion from the statistics of the United States Army; while most English writers (Danson, Aitken, Roberts, &c.) regard the 25th as the year of mature growth, and Dr. Beddoe places it as early as the 23rd year, admitting, however, that a slight increase may take place after this age. The difference of opinion on this subject arises, no doubt, from the faulty method of relying on the measurements of many different individuals, instead of measuring the same individuals from year to year until growth ceases. The elimination of the weak and ill-developed by death, the difficulty of following the same class, and all the members of the class, through successive years, and the selection of special classes (*i.e.* recruits whose ages are never certain), invalidate all conclusions as to the period of maturity drawn from statistics of measurements of many different persons; but, allowing for these sources of error, and judging by the run of the curves formed by the means and averages, it is probable that little actual growth takes place after the age of 21, and that it entirely ceases by the 25th year. It is evident, moreover, from Table XVI., that the full stature is attained earlier in the well-fed and most favoured class (Class I.) than in the ill-fed and least favoured classes of the community (Class IV.).

62. It is difficult to understand, moreover, how any increase of stature can take place after the bones of the skeleton have become consolidated, and the epiphyses firmly united to the body of their respective bones; and the last of these unions in the long bones, on which the stature depends, occurs about the 23rd year. In adopting the 23rd year for men and the 20th for women as the ages of the attainment of maturity the committee was influenced by these considerations, and a desire to understate rather than overstate its case, and to embrace as large a number of observations as possible in its tables. In inquiries of this kind there is generally a slight amount of unconscious selection, very small persons being passed over, or having objections to being measured; and any deficiency of this kind will be balanced by the loss of growth which may occur after the age of 23 years. Females attain to maturity earlier than males, and the age of full growth has been fixed three years earlier for them.

Influence of Advancing Age.

63. The maintenance of the stature throughout life as shown by Tablo XVI. is a new and unexpected fact, but it is probably due to the survival of the taller and better developed members of the population, and the elimination by disease or death of the smaller and feebler ones. Quetelet

TABLE XVI.—Showing the Average STATURE (without shoes), at all Ages, of different Classes of the Population of Great Britain.

Males.

Age last Birth-day	General Population. All Classes. Town and Country			Class I. Professional Classes. Town and Country			Class II. Commercial Classes. Towns			Class III. Labouring Classes. Country			Class IV. Artisans. Towns		
	No. Obs.	Average Height. Inches	Increase. Inches.	No. Obs.	Average Height. Inches.	Increase. Inches.	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches.	Increase Inches	No. Obs.	Average Height. Inches.	Increase. Inches
Birth	451	19·52	—	—	—	—	—	—	—	—	—	—	451	19·52	—
0–1	2	27·00	—	—	—	—	—	—	—	2	—	—	—	—	—
1–	1	33·50	—	—	—	—	—	—	—	1	—	—	—	—	—
2–	5	33·70	—	—	—	—	—	—	—	5	—	—	—	—	—
3–	33	36·82	—	—	—	—	—	—	—	22	37·41	—	11	36·23	—
4–	107	38·46	1·64	—	—	—	—	—	—	19	39·30	1·89	88	37·63	1·40
5–	201	41·03	2·57	—	—	—	—	—	—	34	42·35	3·05	167	39·72	2·09
6–	266	44·00	2·97	—	—	—	1	45·50	—	34	44·59	2·24	231	41·90	2·18
7–	307	45·97	1·97	—	—	—	4	47·50	—	39	45·81	1·22	264	44·60	2·70
8–	1524	47·05	1·08	—	—	—	61	47·60	—	324	47·09	1·28	1139	46·46	1·86
9–	2278	49·70	2·65	22	50·80	—	211	50·03	2·43	485	49·11	2·02	1560	48·88	2·42
10–	1551	51·84	2·14	101	53·69	2·89	331	52·04	2·01	783	50·93	1·82	336	50·72	1·84
11–	1766	53·50	1·66	242	55·23	1·54	687	53·76	1·72	597	52·32	1·39	240	52·68	1·96
12–	1981	54·99	1·49	490	57·29	2·06	902	55·29	1·53	395	53·67	1·35	194	53·72	1·04
13–	2743	56·91	1·92	869	59·08	1·79	857	57·43	2·14	403	55·31	1·64	614	55·81	2·09
14–	3428	59·33	2·42	966	61·29	2·21	800	59·47	2·04	9	57·94	2·63	1653	58·61	2·80
15–	3498	62·24	2·91	974	63·61	2·32	544	62·19	2·72	515	61·82	3·88	1465	61·36	2·75
16–	2780	64·31	2·07	1102	66·23	2·62	110	64·55	2·36	177	63·62	1·80	1391	62·85	1·49
17–	2745	66·24	1·93	1852	67·81	1·58	107	66·59	2·04	75	65·87	2·25	711	64·70	1·85
18–	2305	66·96	·72	1724	68·26	·45	62	67·44	·85	148	66·53	·66	371	65·60	·90
19–	1434	67·29	·33	951	68·58	·32	63	67·55	·11	143	66·87	·34	277	66·17	·57
20–	880	67·52	·23	461	69·08	—	61	67·58	·03	183	66·93	·06	175	66·50	·33
21–	757	67·63	·11	364	68·70	·12	51	67·79	·21	177	67·15	·22	165	66·55	·05
22–	558	67·68	·05	227	68·94	—	53	67·82	·03	169	67·35	·20	109	66·60	·05
23–	592	67·48	—	114	68·73	·03	59	67·42	—	274	67·38	·03	145	66·40	—
24–	517	67·73	·05	57	68·82	·09	62	68·09	·27	258	67·47	·09	140	66·55	—
25–							47	67·93	—	218	67·52	·05	92	66·40	—
26–							47	68·07	—	194	67·46	—	74	66·46	—
27–	1576	67·80	·07	107	69·14	·32	27	68·13	·04	162	67·76	·24	66	66·67	·07
28–							33	67·65	—	208	67·31	—	59	66·65	—
29–							26	67·96	—	163	67·54	—	53	66·82	·15
30–35	1886	68·00	·20	52	69·61	·37	85	67·70	—	745	67·59	—	180	66·65	—
35–40							82	68·07	—	631	67·62	—	111	67·08	·26
40–50	1148	67·96	—	46	69·38	—	79	68·09	—	943	67·56	—	80	66·80	—
50–60	198	67·92	—	13	69·50	—	16	67·69	—	147	68·06	·30	22	66·45	—
60–70	44	67·41	—	5	69·10	—	3	66·16	—	34	67·88	—	2	66·50	—
70–	12	69·22	1·22	—	—	—	1	68·50	—	11	69·95	1·89	—	—	—
Total Obs.	37574	—	—	10739	—	—	5472	—	—	8727	—	—	12636	—	—

TABLE XVII.—Showing the Average STATURE (without shoes), at all Ages, of different Classes of the Population of Great Britain.

Females.

Age last Birth-day	General Population. All Classes. Town and Country			Class I. Professional Classes. Town and Country			Class II. Commercial Classes. Towns			Class III. Labouring Classes. Country			Class IV. Artisans. Towns		
	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches.	Increase. Inches	No. Obs.	Average Height. Inches	Increase. Inches	No. Obs.	Average Height. Inches	Increase. Inches
Birth	466	19·31	—	—	—	—	—	—	—	—	—	—	466	19·31	—
0–1	6	24·83	5·52	—	—	—	—	—	—	—	—	—	6	24·83	5·52
1–	9	27·50	2·67	—	—	—	1	28·50	—	—	—	—	7	27·38	2·55
2–	6	32·33	4·83	—	—	—	—	—	—	—	—	—	6	32·00	4·62
3–	43	36·23	3·90	—	—	—	11	37·68	—	8	36·78	—	24	35·33	3·33
4–	99	38·26	2·03	—	—	—	12	38·50	·82	19	38·97	2·19	68	37·30	1·97
5–	157	40·55	2·29	—	—	—	10	40·00	1·50	43	41·87	2·90	104	39·77	2·47
6–	189	42·88	2·33	—	—	—	14	42·50	2·50	44	43·43	1·56	131	41·84	2·07
7–	173	44·45	1·57	—	—	—	30	44·43	1·93	47	45·35	1·92	96	43·56	1·72
8–	432	46·60	2·15	—	—	—	18	47·16	2·73	119	47·10	1·75	295	45·55	1·99
9–	499	48·73	2·13	—	—	—	42	49·90	2·74	175	48·93	1·83	282	47·36	1·81
10–	480	51·05	2·32	11	53·41	—	52	51·44	1·54	149	50·40	1·47	268	48·96	1·60
11–	441	53·10	2·05	22	55·04	1·63	87	53·33	1·89	115	52·48	2·08	217	51·54	2·58
12–	225	55·66	2·56	23	57·41	2·37	87	55·68	2·35	22	55·59	3·11	93	53·98	2·44
13–	206	57·77	2·11	68	59·03	1·62	66	58·47	2·79	14	57·36	1·77	58	56·22	2·24
14–	240	59·80	2·03	79	60·78	1·75	86	60·62	2·15	12	59·16	1·80	63	58·56	2·34
15–	201	60·93	1·13	70	62·11	1·33	98	61·28	·66	—	—	—	33	59·41	0·85
16–	136	61·75	·82	49	62·54	·43	82	61·56	0·28	—	—	—	5	61·16	1·75
17–	88	62·52	·77	20	62·83	·29	68	62·22	·66	—	—	—	—	—	—
18–	62	62·44	—	25	62·84	·01	37	62·05	—	—	—	—	—	—	—
19–	98	62·75	·23	48	63·40	·56	50	62·10	—	—	—	—	—	—	—
20–	130	62·98	·23	59	63·39	—	71	62·58	·36	—	—	—	—	—	—
21–	60	63·03	·05	24	63·63	·23	36	62·44	—	—	—	—	—	—	—
22–	53	62·87	—	13	63·53	—	40	62·22	—	—	—	—	—	—	—
23–	24	63·01	—	13	63·42	—	11	62·66	·08	—	—	—	—	—	—
24–	21	62·70	—	5	63·60	—	—	—	—	—	—	—	16	61·81	·65
25–30	43	62·02	—	19	62·97	—	—	—	—	—	—	—	24	61·08	—
30–35				8	63·25	—	—	—	—	—	—	—	—	—	—
35–40				—	—	—	—	—	—	—	—	—	11	60·90	—
40–50	30	61·15	—	—	—	—	—	—	—	—	—	—	5	60·60	—
50–60				—	—	—	—	—	—	—	—	—	1	61·50	—
60–70				—	—	—	—	—	—	—	—	—	2	60·50	—
70–				—	—	—	—	—	—	—	—	—	3	60·16	—
Total Obs.	4616	—	—	556	—	—	1009	—	—	767	—	—	2284	—	—

TABLE XVIII.—Showing the Average WEIGHT (including clothes), at all Ages, of different Classes of the Population of Great Britain.

Males.

Age last Birth-day	General Population. All Classes. Town and Country			Class I. Professional Classes. Town and Country			Class II. Commercial Classes. Towns.			Class III. Labouring Classes. Country			Class IV. Artisans. Towns		
	No. Obs.	Average Weight. Pounds	Increase. Pounds	No. Obs.	Average Weight. Pounds.	Increase. Pounds.	No. Obs.	Average Weight. Pounds.	Increase. Pounds.	No. Obs.	Average Weight. Pounds.	Increase. Pounds.	No. Obs.	Average Weight. Pounds.	Increase. Pounds.
Birth	451	7·1	—	—	—	—	—	—	—	—	—	—	451	7·1	—
0–1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2–	2	32·5	—	—	—	—	—	—	—	2	32·5	—	—	—	—
3–	41	34·0	1·5	—	—	—	—	—	—	11	33·1	—	30	35·0	—
4–	102	37·3	3·3	—	—	—	1	37·5	—	15	35·8	2·7	86	38·6	3·6
5–	193	39·9	2·6	—	—	—	—	—	—	29	38·9	3·1	164	40·9	2·3
6–	224	44·4	4·5	—	—	—	—	—	—	35	44·2	5·3	189	44·6	3·7
7–	246	49·7	5·3	—	—	—	4	51·3	3·8	37	47·2	3·0	205	50·7	6·1
8–	820	54·9	5·2	—	—	—	63	55·5	4·2	286	54·8	7·6	471	54·3	3·6
9–	1425	60·4	5·5	—	—	—	211	62·3	6·8	415	60·5	5·7	799	58·3	4·0
10–	1464	67·5	7·1	92	74·0	—	370	65·2	2·9	721	67·0	6·5	281	64·0	5·7
11–	1599	72·0	4·5	185	78·7	4·7	686	68·0	2·8	553	72·2	5·2	175	69·0	5·0
12–	1786	76·7	4·7	369	84·9	6·2	905	73·2	5·2	366	75·9	3·7	146	73·0	4·0
13–	2443	82·6	5·9	621	91·6	6·7	854	80·1	6·9	328	79·7	3·8	640	79·0	6 0
14–	2952	92·0	9·4	748	102·2	10·6	799	89·5	9·4	9	89·2	9·5	1396	87·3	8·3
15–	3118	102·7	10·7	652	114·3	12·1	344	99·4	9·9	676	100·6	11·4	1446	96·4	9·1
16–	2235	119·0	16·3	834	129·5	15·2	55	117·2	17·8	169	117·2	16·6	1177	112·2	15·8
17–	2496	130·9	11·9	1705	141·7	12·2	38	128·8	11·6	80	131·5	14·3	673	121·5	9·3
18–	2150	137·4	6·5	1638	146·4	4·7	39	135·1	6·3	135	138·7	7·2	338	129·3	7·8
19–	1438	139·6	2·2	940	148·5	2·1	69	138·6	3·5	140	140·2	1·5	289	131·1	1·8
20–	851	143·3	3·7	451	152·4	3·9	52	140·1	1·5	175	144·3	4·1	173	136·4	5·3
21–	738	145·2	1·9	365	152·7	·3	52	143·9	3·8	164	147·8	3·5	157	136·2	—
22–	542	146·9	1·7	215	152·8	·1	51	145·5	1·6	167	150·6	2·8	109	138·6	2·2
23–	551	147·8	·9	112	151·5	—	57	146·8	1·3	279	152·8	2·2	103	140·2	1·6
24–	483	148·0	·2	56	149·6	—	57	147·1	·3	250	151·9	—	120	143·4	3·2
25–							45	148·5	1·4	224	154·1	1·3	61	139·9	—
26–							46	154·1	5·6	192	154·1	—	58	142·2	—
27–	1523	152·3	4·3	115	156·3	3·5	26	149·2	—	171	156·7	2·6	56	146·9	3·5
28–							33	156·1	2·0	213	155·1	—	50	148·0	1·1
29–							26	154·3	—	161	158·0	1·3	46	148·1	·1
30–35	964	159·8	7·5	24	171·5	15·2	87	158·5	2·4	700	159·2	1·2	153	150·1	2·0
35–40	840	164·3	4·5	24	173·5	—	80	166·6	8·1	631	160·5	1·3	105	156·5	6·4
40–50	1140	163·3	—	44	172·5	1·0	72	168·6	2·0	911	162·0	1·5	113	151·7	—
50–60	179	166·1	1·8	13	174·5	2·0	16	173·4	4·8	129	170·9	8·9	21	145·6	—
60–70	35	158·1	2·0	5	164·5	—	3	165·7	—	24	170·9	—	3	130·8	—
70–	12	182·1	—	—	—	—	1	189·0	—	11	175·3	4·4	—	—	—
Total Obs.	33043	—	—	9208	—	—	5142	—	—	8409	—	—	10284	—	—

TABLE XIX.—Showing the Average WEIGHT (including clothes), at all Ages, of different Classes of the Population of Great Britain.

Females.

Age last Birth-day	General Population. All Classes. Town and Country			Class I. Professional Classes. Town and Country			Class II. Commercial Classes. Towns only			Class III. Labouring Classes. Country only			Class IV. Artisan Classes. Towns only		
	No. Obs.	Average Weight. Pounds	Increase. Pounds	No. Obs.	Average Weight. Pounds	Increase. Pounds	No. Obs.	Average Weight. Pounds	Increase. Pounds	No. Obs.	Average Weight. Pounds	Increase. Pounds	No. Obs.	Average Weight. Pounds	Increase. Pounds
Birth	466	6·9	—	—	—	—	—	—	—	—	—	—	466	6·9	—
0–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1–	8	20·1	—	—	—	—	1	22·5	—	—	—	—	7	19·6	12·7
2–	9	25·3	5·2	—	—	—	—	—	—	—	—	—	9	25·3	5·7
3–	30	31·6	6·3	—	—	—	11	30·9	—	8	33·0	—	22	30·8	5·5
4–	97	36·1	4·5	—	—	—	12	37·9	7·9	17	34·6	1·6	68	35·8	5·0
5–	160	39·2	3·1	—	—	—	18	38·8	0·9	44	38·4	3·8	108	40·3	4·5
6–	178	41·7	2·5	—	—	—	13	41·4	2·6	43	40·5	2·1	122	43·1	2·8
7–	148	47·5	5·8	7	51·8	—	31	45·4	4·0	42	46·8	6·3	99	46·2	3·1
8–	330	52·1	4·6	6	52·5	·7	12	52·5	7·1	140	51·9	5·1	172	51·8	5·6
9–	535	55·5	3·4	17	55·4	2·9	23	55·0	2·5	209	56·5	4·6	286	55·2	3·4
10–	495	62·0	6·5	37	62·9	7·5	23	62·9	7·9	171	61·8	5·3	264	60·5	5·3
11–	456	68·1	6·1	61	69·9	7·0	41	68·5	5·6	130	67·1	5·3	224	66·8	6·3
12–	419	76·4	8·3	55	79·7	9·8	55	77·3	8·8	126	75·7	8 6	183	74·9	8·1
13–	209	87·2	10·8	63	89·8	10·1	60	88·2	10·9	21	84·0	8·3	65	84·9	10·0
14–	229	96·7	9·5	75	98·8	9·0	81	96·3	8·1	12	94·0	10·0	61	97·7	12·8
15–	187	106·3	9·6	60	107·3	8·5	91	104·1	7·8	—	—	—	36	107·6	9·9
16–	128	113·1	6·8	49	113·9	6·6	75	112·2	8·1	—	—	—	—	—	—
17–	74	115·5	2·4	14	116·8	2·9	59	114·3	2·1	—	—	—	—	—	—
18–	64	121·1	5·6	26	123·1	6·3	38	119·1	4·8	—	—	—	—	—	—
19–	97	123·8	2·7	47	125·5	2·4	50	122·1	3·0	—	—	—	—	—	—
20–	128	123·4	·6	58	126·6	1·1	70	120·3	—	—	—	—	—	—	—
21–	59	121·8	—	23	125·3	—	36	118·3	—	—	—	—	—	—	—
22–	53	123·4	—	14	122·8	—	37	124·1	2·0	—	—	—	—	—	—
23–	29	124·1	·7	12	128·7	2·1	16	119·4	—	—	—	—	—	—	—
24–	19	120·8	—	5	120·5	—	—	—	—	—	—	—	—	—	—
25–30	43	120·0	—	19	119·1	—	—	—	—	—	—	—	—	—	—
30–35 } 35–40 }	23	120·8	—	8	120·6	—	—	—	—	—	—	—	—	—	—
40–45	9	118	—	—	—	—	—	—	—	—	—	—	—	—	—
45–50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50–60	3	104	—	—	—	—	—	—	—	—	—	—	—	—	—
60–70	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
70–	3	106·0	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Obs.	4685	—	—	656	—	—	853	—	—	963	—	—	2192	—	—

TABLE XX.—Summary Table showing the average STATURE, WEIGHT, and their relation

Age last birth-day	Height without shoes, in inches		Weight with clothes, in lbs.		Chest-girth, empty, in inches		Strength: drawing-power, in lbs.		Span of arms across the back, in inches		Ratio: weight divided by height		Ratio: weight divided by chest-girth	
	M.	F.	M.	F.	M.	F.	M.	F	M.	F.	M.	F.	M.	F.
Birth	19·52	19·31	7·1	6·9	13·25	12·65	—	—	—	—	—	—	—	—
0–1	27·00	24·83	—	—	—	—	—	—	—	—	—	—	—	—
1–2	33·50	27·50	—	—	—	—	—	—	—	—	—	—	—	—
2–	33·70	32·33	32·5	—	—	—	—	—	—	—	·96	—	—	—
3–	36·82	36·05	34·0	31·9	—	—	—	—	—	—	·92	0·87	—	—
4–	38·46	38·13	37·3	35·5	—	—	—	—	—	—	·99	·93	—	—
5–	41·03	40·82	39·9	39·6	—	—	—	—	—	—	·97	·97	—	—
6–	44·00	42·63	44·4	42·4	—	—	—	—	—	—	1·01	1·00	—	—
7–	45·97	44·45	49·7	46·7	—	—	—	—	43·10	45·83	1·08	1·05	—	—
8–	47·05	46·60	54·9	52·2	—	—	—	17·5	47·56	46·50	1·16	1·12	—	—
9–	49·70	48·73	60·4	55·5	—	—	—	15·0	49·07	48·39	1·22	1·14	—	—
10–	51·84	51·05	67·5	62·0	26·10	—	—	15·1	50·64	49·92	1·30	1·21	2·59	—
11–	53·50	53·10	72·0	68·1	26·53	—	37·5	17·6	51·98	52·41	1·35	1·28	2·72	—
12–	54·99	55·66	76·7	76·4	27·20	—	38·7	18·8	54·03	55·04	1·39	1·37	2·82	—
13–	56·91	57·77	82·6	87·0	28·03	—	44·2	22·3	55·51	58·06	1·45	1·51	2·95	—
14–	59·33	59·80	92·0	96·7	28·46	—	47·0	25·5	57·15	59·04	1·55	1·62	3·23	—
15–	62·24	60·93	102·7	104·8	29·74	—	52·2	29·6	—	60·79	1·65	1·72	3·46	—
16–	64·31	61·75	119·0	112·7	31·53	—	58·2	31·8	—	61·66	1·85	1·82	3·78	—
17–	66·24	62·52	130·9	114·9	33·64	—	67·8	33·9	—	62·52	1·98	1·84	3 89	—
18–	66·96	62·44	137·4	117·7	34·19	—	74·2	38·9	—	62·50	2·05	1·89	4·02	—
19–	67·29	62·75	139·6	123·7	34·49	—	76·4	40·8	—	62·69	2·07	1·97	4·05	—
20–	67·52	62·98	143·3	123·2	34·98	—	77·9	42·0	—	62·49	2·12	1·96	4·09	—
21–	67·63	63·03	145·2	121·2	35·25	—	80·2	41·9	—	62·19	2·15	1·92	4·13	—
22–	67·68	62·87	146·9	124·2	35·33	—	81·7	42·9	—	62·35	2·17	1·97	4·16	—
23–	67·48	63·01	147·8	126·4	35·62	—	79·7	38·5	—	62·36	2·19	2·06	4·15	—
24–	67·72	62·70	148·0	120·6	35·82	—	80·9	39·2	—	62·22	2·19	1·92	4·13	—
25–	67·75		149·2								2·20			
26–	67·78		151·7								2·23			
27–	67·92	62·02	152·3	120·1	36·18	—	83·5	40·8	—	62·61	2·39	1·94	4·21	—
28–	67·70		153·9								2·27			
29–	67·87		154·2								2·27			
30–	67·89		159·8	121·0	37·08	—	77·5	46·2	—	62·10	2·35		4·37	—
35–	68·09		164·3								2·41			
40–	67·96		163·1	118·6	37·58	—	76·5				2·39		4·38	—
50–	67·92	61·15	166·1	—							2·44	1·96		
60–	67·41		158·1	—	—	—	74·6	38·1	—	60·29	2·24			
70–	69·22		182·1	—	—	—	—				2·62			

Chest-girth, Strength, and Span of Arms of both Sexes and of all Ages, to each other.

Ratio: weight divided by strength		Relation of span of arms to height		Difference between the two sexes: females compared with males								Age last Birth-day
				Height		Weight		Strength		Span of arms		
M.	F.	M.	F.	Actual	Per cent.	Actual	Per cent.	Actual	Per cent.	Actual	Per cent.	
				inches		lbs.						
—	—	—	—	−0·21	−1·07	− 0·2	− 2·81	—	—	—	—	Birth
—	—	—	—	—	—	—	—	—	—	—	—	0–1
—	—	—	—	—	—	—	—	—	—	—	—	1–2
—	—	—	—	—	—	—	—	—	—	—	—	2–
—	—	—	—	−0·77	−2·09	− 2·1	− 6·17	—	—	—	—	3–
—	—	—	—	−0·33	−0·86	− 1·8	− 4·82	—	—	—	—	4–
—	—	—	—	−0·21	−0·51	− 0·3	− 0·75	—	—	—	—	5–
—	—	—	—	−1·37	−3·11	− 2·0	− 4·50	—	—	—	—	6–
—	—	−2·87	+1·38	−1·52	−3·30	− 3·0	− 6·04	—	—	+2·7	+6·2	7–
—	2·98	+ ·51	− ·10	−0·45	−0·99	− 2·7	− 4·92	—	—	−1·0	−2·1	8–
—	3·70	− ·63	− ·34	−0·97	−1·95	− 4·9	− 8·11	—	—	−0·6	−1·2	9–
—	4·11	−1·20	−1·13	−0·79	−1·52	− 5·5	− 8·15	—	—	−0·7	−1·3	10–
1·92	3·87	−1·52	− ·69	−0·40	−0·74	− 3·9	− 5·41	−19·9	−53·0	+0·4	−0·7	11–
1·98	4·06	− ·96	− ·62	+0·67	+1·22	− 0·3	− 0·39	−19·9	−51·4	+1·0	+1·8	12–
1·87	3·90	−1·40	+ ·29	+0·86	+1·51	+ 4·4	+ 5·32	−21·9	−49·5	+2·5	+4·5	13–
1·96	3·79	−2·18	− ·76	+0·47	+0·79	+ 4·7	+ 5·11	−21·5	−45·7	+1·9	+3·3	14–
1·97	3·54	—	− ·14	−1·31	−2·10	+ 2·1	+ 2·04	−22·6	−43·3	—	—	15–
2·04	3·54	—	− ·09	−2·56	−4·00	− 6·3	− 5·30	−26·4	−45·3	—	—	16–
1·93	3·46	—	—	−3·72	−5·61	−16·	−12·21	−39·	−50·0	—	—	17–
1·85	3·03	—	+ ·06	−4·52	−6·75	−19·7	−14·34	−35·3	−47·5	—	—	18–
1·83	3·03	—	− ·06	−4·54	−6·74	−15·9	−11·39	−35·6	−46·6	—	—	19–
1·84	2·93	—	− ·49	−4·54	−6·72	−20·1	−14·02	−35·9	−46·0	—	—	20–
1·81	2·89	—	− ·84	−4·60	−6·30	−24·0	−16·53	−38·3	−47·7	—	—	21–
1·80	2·89	—	− ·52	−4·81	−7·10	−22·7	−15·45	−38·8	−47·2	—	—	22–
1·85	3·28	—	− ·65	−4·41	−6·63	−21·4	−14·49	−41·2	−51·7	—	—	23–
1·83	3·08	—	− ·48	−5·02	−7·41	−27·4	−18·51	−41·7	−50·1	—	—	24–
1·82	2·94	—	− ·41	−5·82	−8·50	−38·	−24·97	−42·7	−51·0	—	—	25– 26– 27– 28– 29–
2·09	2·61	—	—	—	—	−41·0	−25·31	−31·3	−40·4	—	—	30– 35–
2·13		—	+ ·05	−6·93	10·18	−44·5	−27·34	−37·4	−50·0	—	—	40–
2·23	3·11	—	—	—	—							50–
—		—	—	—	—	—	—	—	—	—	—	60–
—		—	—	—	—	—	—	—	—	—	—	70–

has stated that man attains his maximum height at the age of 30 years, and maintains it up to 50 years, after which it begins to recede, and at 90 it has lost three inches. This may be, and probably is, true of individuals if measured from year to year, but it does not appear to be true of the population in the aggregate. The loss of stature resulting from the degeneration and loss of tissue, and the stooping position assumed by old people, is more than counterbalanced by the survival of a greater number of individuals who are above the average in height. The uniform increase in the weight and chest-girth throughout adult life also confirms this view.

Industrial Schools.

64. The statistics referring to Industrial School children of both sexes are given in a separate form, as illustrating the physique of children bred under the most unfavourable conditions of life. Boys of this class of the age of 14 years are nearly seven inches (6·83) shorter of stature and $24\frac{3}{4}$ lbs. lighter in weight than the 1st or Standard Class of the foregoing tables. The returns sent in by Mr. R. Sutton from the Swinton School, near Manchester, are the most complete in all their details which the Committee has received from any source, and they may be accepted as models of what such returns ought to be.

TABLE XXI.—Comparative Table of Boys and Girls in Industrial Schools.

Age	Number of Observations		Height		Weight		Chest-girth		Span of Arms	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
			inches	inches	lbs.	lbs.	inches	inches	inches	inches
16–	7	—	57·64	—	93·92	—	29·25	—	57·50	—
15–	58	1	55·43	55·50	85·50	67·50	28·30	—	57·17	58·50
14–	102	33	54·46	55·00	77·35	81·25	27·29	—	54·72	54·21
13–	221	58	53·23	52·98	72·31	72·76	26·31	—	52·45	53·60
12–	205	66	51·79	51·16	67·40	68·25	25·85	—	50·10	51·28
11–	158	63	49·11	51·48	63·19	60·96	24·17	—	49·15	49·11
10–	191	60	48·09	47·70	56·76	56·00	23·97	—	47·46	47·21
9–	100	70	47·02	46·44	52·40	52·77	23·30	—	45·30	45·41
8–	69	66	44·61	44·68	47·13	47·79	22·58	—	43·20	43·46
7–	64	45	43·54	42·38	45·70	44·05	22·16	—	41·23	41·95
6–	46	47	41·14	41·15	40·43	40·66	21·95	—	40·30	39·50
5–	37	43	38·63	39·22	36·68	36·98	21·42	—	38·10	38·25
4–	9	19	36·27	37·07	33·61	34·09	20·50	—	35·00	35·90
3–	5	10	34·50	35·50	30·50	32·50	—	—	33·25	32·50
2–	—	11	—	31·95	—	26·77	—	—	—	29·50
1–	—	4	—	27·00	—	16·21	—	—	—	—
6 & under 12 months	—	4	—	26·25	—	16·66	—	—	—	—
0 & under 6 months	1	1	23·50	27·50	11·00	12·50	—	—	—	—
Total	1,273	601								

TABLE XXII.—Statement of the Percentage Proportion in each Class, as regards COLOUR OF EYES AND HAIR, of Boys and Girls, of English Parentage, in Industrial and Workhouse Schools, at each age.

Ages last birthday	Boys								Girls							
	Number of observations	Eyes light, with			Eyes dark, with			Eyes light brown, with light or dark hair	Number of observations	Eyes light, with			Eyes dark, with			Eyes light brown and green, with light or dark hair
		Light hair	Dark hair	Red hair	Dark hair	Fair hair	Red hair			Light hair	Dark hair	Red hair	Dark hair	Fair hair	Red hair	
		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
16	7	43·0	29·0	—	29·0	—	—	—	1	—	—	—	—	—	—	—
15	61	37·7	29·5	5·0	24·6	—	1·6	1·6	9	55·6	11·1	11·1	11·1	—	—	11·1
14	89	49·6	18·0	2·2	25·8	1·1	1·1	2·2	46	54·2	4·4	8·8	17·4	6·5	2·2	6·5
13	182	49·0	10·0	4·4	28·6	0·5	3·7	3·8	67	41·3	1·6	13·4	35·6	—	1·6	6·0
12	165	47·3	16·0	3·0	20·4	1·8	2·2	7·3	64	48·4	7·8	7·8	28·1	—	6·3	1·6
11	131	47·0	10·5	6·7	24·6	4·5	1·5	5·2	76	56·6	5·2	6·6	14·5	4·0	7·9	5·2
10	168	50·0	14·3	2·4	27·4	—	3·5	2·4	66	63·7	2·5	2·5	25·8	—	—	4·5
9	85	54·1	4·7	1·2	34·1	1·2	4·7	—	69	60·9	2·9	2·9	29·0	1·4	2·9	—
8	57	49·1	3·5	12·3	24·5	1·8	3·5	5·3	57	60·0	1·7	1·7	31·1	3·3	—	7.0
7	48	54·2	8·3	2·1	33·3	—	—	2·1	37	64·9	5·4	5·4	16·2	8·1	—	—
6	31	58·1	6·4	3·2	25·0	—	—	6·4	30	80·0	3·3	—	6·7	6·7	—	3·3
5	31	58·1	6·4	—	32·3	3·2	—	—	24	46·0	12·3	—	33·4	8·3	—	—
4	9	44·4	—	—	44·4	1	—	—	7	42·7	—	—	42·9	—	—	14·2
3	5	60·0	—	—	40·0	—	—	—	4	50·0	—	—	50·0	—	—	—
2	—	—	—	—	—	—	—	—	3	66·0	—	—	34·0	—	—	—
Total	1,072	49·5	12·1	3·8	26·8	1·6	2·4	3·8	560	56·5	4·3	5·1	25·8	2·7	2·9	2·7

TABLE XXIII.—Comparison of Boys and Girls, at different Ages, in Industrial School at Swinton, near Manchester.

Age	No. of Observations		Height		Weight		Chest-girth		Breathing capacity		Strength of arm. Drawing power		Sight. Test dots distinguished at distance of feet	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
			inches	inches	lbs.	lbs.	inches	inches	cubic inches	cubic inches	lbs.	lbs.	ft. in.	ft. in.
14	6	21	55·0	54·4	78·7	80·9	28·3	29·0	189	177	40·0	33·0	27·9	38·1
13	28	27	52·5	51.1	70·0	71·3	26·6	27·3	166	143	37·3	27·6	30·9	37·2
12	41	29	54·0	49·9	65·4	64·6	25·9	27·6	166	138	36·0	27·6	32·6	36·7
11	22	31	50·0	49·4	63·1	60·3	25·3	27·5	153	145	34·2	25·4	32·3	39·0
10	32	27	48·2	47·0	57·1	55·4	23·6	26·9	140	124	26·7	19·5	28·4	34·8
9	32	25	46·7	45·8	52·7	52·0	23·0	26·2	132	126	21·7	18·0	24·2	31·7
8	24	28	43·8	44·4	47·0	47·3	22·6	25·7	117	112	18·4	17·0	22·8	36·5
7	32	20	43·6	41·2	46·2	42·4	22·2	25·5	77	83	18·5	12·5	23·8	27·6
6	28	19	40·7	39·0	39·9	37·2	21·4	21·0	48	54	11·5	8·5	19·8	34·3
5	12	15	38·9	38·6	35·8	34·8	20·8	20·6	38	41	6·4	6·8	16·4	19·9
4	3	3	35·0	35·0	32·3	29·7	20·0	19·3	22	30	4·0	4·3	9·6	13·0
3	1	—	34·6	—	28·0	—	20·0	—	20	—	—	—	—	—
Total	261	245	—	—	—	—	—	—	—	—	—	—	—	—

Colour of Eyes and Hair. Percentage proportion in each Class.

	Eyes light, with			Eyes dark, with			Light brown, green, or exceptional eyes, with light or dark hair	Total
	Hair light	Hair dark	Hair red	Hair dark	Hair fair	Hair red		
Boys 261 English	54·6	12·7	1·7	20·1	1·2	3·4	6·3	100
Boys 261 Irish	65·0	3·7	3·1	15·3	5·5	7	6·7	100
Girls 245 English	39·8	26·1	3·4	20·5	—	1·1	9·1	100
Girls 245 Irish	50·0	18·3	6·1	23·2	—	1·2	1·2	100

Physical Improvement or Degeneracy of the Population.

65. Few statistics are in existence which help to throw light on this subject. It is generally believed that the population in the manufacturing towns of the North of England is rapidly degenerating, but a comparison of the measurements of stature and weight given in the Report of the Factory Commissioners of 1833, and in the Report to the Local Government Board on 'Changes in Hours and Ages of Employment of Children and Young Persons in Textile Factories,' 1873, shows that this is not the case. On the contrary, an examination of Table XXIV., showing these measurements, indicates a slight but uniform increase in stature, and a very large increase in weight, at corresponding ages. The increase in weight amounts to a whole year's gain, and a child of 9 years of age in 1873 weighed as much as one of 10 years in 1833, one of 10 as much as one of 11, and one of 11 as much as one of 12 years in the two periods respectively.

66. As an example of the condition of a class living under most favourable conditions, a table (XXV.) showing the measurements of the boys in the Friends' (Quakers') School at York, extending over a period of

twenty-seven years, is given. Allowing for one or two obvious errors of observation, the general run of the figures is very uniform, the statures remaining stationary, while there is a slight improvement in the weight at the higher ages in the last nine years.

TABLE XXIV.—Showing the average STATURE and WEIGHT of Factory Children at an interval of 40 years, 1833–1873. (Stanway and Roberts.)

STATURE.

Age	Boys				Girls			
	1833		1873		1833		1873	
	No.	Inches	No.	Inches	No.	Inches	No.	Inches
9	17	48·14	126	48·30	30	47·97	144	48·31
10	48	49·79	256	49·85	41	49·62	201	50·33
11	53	51·26	196	51·59	51	51·15	174	51·21
12	42	53·38	175	53·30	80	53·70	—	—
				WEIGHT.				
	No.	lbs.	No.	lbs.	No.	lbs.	No.	lbs.
9	17	51·76	136	58·15	30	51·31	137	55·87
10	48	57·00	247	60·19	41	54·80	179	60·59
11	53	61·84	189	67·72	63	59·69	180	65·37
12	42	65·97	167	69·76	80	66·08	—	—

TABLE XXV.—Showing the average STATURE and WEIGHT of Boys in the York Friends' School, for 27 years, 1853–1879.

Age last Birth-day	No. of Obs.	STATURE				WEIGHT			
		27 yrs. 1853 to 1879	9 yrs. 1853 to 1861	9 yrs. 1862 to 1870	9 yrs. 1871 to 1879	27 yrs. 1853 to 1879	9 yrs. 1853 to 1861	9 yrs. 1862 to 1870	9 yrs. 1871 to 1879
		inches	inches	inches	inches	lbs.	lbs.	lbs.	lbs.
9–	13	51·5	51·4	49·7	53·4	62·9	63·2	*54·2	70·3
10–	86	53·3	53·9	*51·6	54·7	68·5	71·6	*61·1	74·2
11–	261	56·4	56·5	56·1	56·5	79·7	80·3	76·1	81·2
12–	585	57·7	58·0	57·9	57·4	85·8	86·2	86·1	85·4
13–	874	59·9	60·6	59·9	59·6	95·4	96·9	95·0	95·0
14–	1117	62·1	62·1	62·3	61·9	106·0	105·8	107·0	105·4
15–	1174	64·2	63·9	64·3	64·2	116·6	113·5	117·2	117·2
16–	515	66·1	65·4	66·1	66·3	127·8	122·2	126·6	130·2
17–	36	67·2	—	67·0	67·4	136·3	—	130·0	138·6
	4661								

* These values are too low, due probably to some error of observation. Mr. R. Clark, who furnishes the returns, is unable to account for the discrepancies in these year

Conclusion.

67. Attention has been called to some of the principal points of interest in the data collected by the Committee, but in many respects the tables have been left to speak for themselves; and it is not improbable that a study of them will lead some persons to conclusions differing more or less from those given in this Report.[1]

68. The original returns, which the Committee recommend may be placed in the charge of the Anthropological Institute for preservation and future examination, comprise many statistics which could not be introduced into this Report on account of the time and labour required for their analysis and tabulation.

69. The Committee believes that it has laid a substantial foundation for a further and more exhaustive study of the physical condition of a people by anthropometric methods, and that its action will prove it has been useful as an example to other scientific societies and to individuals in stimulating them, as well as directing them, in the methods of making statistical inquiries relative to social questions. The medical officers, managers, or superintendents of many colleges, schools, and charitable institutions have been induced to keep registers of the physical proportions of those under their charge, which will in a few years become valuable records, not only of the physical condition of the inmates of their institutions, but of the sanitary conditions under which they have lived; they will also be available for the further study of the subjects specially treated of in this Report. The Collective Investigation Committee of the British Medical Association propose to carry on the work of this Committee in a direction which it is most needed, namely, by issuing an album in which persons may methodically record at frequent intervals their height, weight, and other physical qualities, together with points in their personal and medical history. The Committee hopes that this habit will be largely adopted and encouraged by the members of the British Association.

70. The Committee has to express its thanks to the numerous contributors to their store of facts, whose names and contributions have been published from time to time in their interim reports, and to numerous friends who, although not contributors themselves, have induced others to give their assistance.

[1] The inquiries relative to *breathing capacity* were abandoned in 1879 on account of the unsatisfactory nature of the returns received previous to that year. The apparatus were faulty.

The statistics relating to *eyesight* were dealt with in the Report for 1881, and the returns since received are not sufficient to require a further discussion of the subject.

The subject of *colour-blindness* was taken up by a Special Committee of the Ophthalmological Society after it had been inaugurated by this Committee, and it was given up on that account. The very interesting report of the Special Committee is published in the first volume of the *Trans. of the Ophthal. Soc.* 1881.

Appendix A.

Specimen of the cards used by the committee for collecting observations, and the instructions for filling them up. The cards are of different colours for the two sexes, and one corner is cut off to make them face one way when arranged by hand. They can be dealt out like playing cards, and much time and trouble is saved in the analysis of their records.

ANTHROPOMETRIC COMMITTEE OF THE BRITISH ASSOCIATION,
22 Albemarle Street, London
(to which address this Card is to be returned after being filled).

Height is to be taken as without shoes, and *weight* in ordinary indoor costume.
Span of Arms is the distance between the tips of the middle fingers extended horizontally, measured across the back (*i.e.* back to the wall).
Colour of Eyes should be stated as grey, light blue, blue, dark blue, light brown, brown, dark brown, green, or black.
Colour of Hair as very fair, fair, golden, red, red brown, light brown, brown, dark brown, black brown, or black.
For *chest-girth*, *breathing capacity*, *strength*, *colour-blindness*, and *eyesight*, see the paper of instructions.
Under *Place of Birth* state Parish and County ; or, if abroad, the name of the Country.
Under *Occupation* state rank or profession.
Race should be stated as English, pure English, very pure English, Irish, pure Irish, very pure Irish, Scotch, pure Scotch, very pure Scotch, or mixed Scotch and English, &c.
Origin, as countryfolk, pure countryfolk, very pure countryfolk, townfolk, pure townfolk, or very pure townfolk, country birth, T. since boy, &c.

FOR A SINGLE SET OF OBSERVATIONS.

Place __________________ Date ______________ 188__

Name (or Initials) ________________________ Sex ________

Age—years __________ months __________

Height, without shoes, inches & eighths Span of arms, inches & eighths ______

Weight, in ordinary indoor costume, lbs. ______ Strength, drawing power, lbs. ______

Chest-girth, inches and eighths ________ Breathing capacity, cub. in. ________

Colour of Eyes ____________ Colour of Hair ____________

Sight:
- Test dots distinguished at, feet ________ Colour-blindness ________
- Test-types No. 1, read at inches
- „ No. 10, „ feet Astigmatism ________

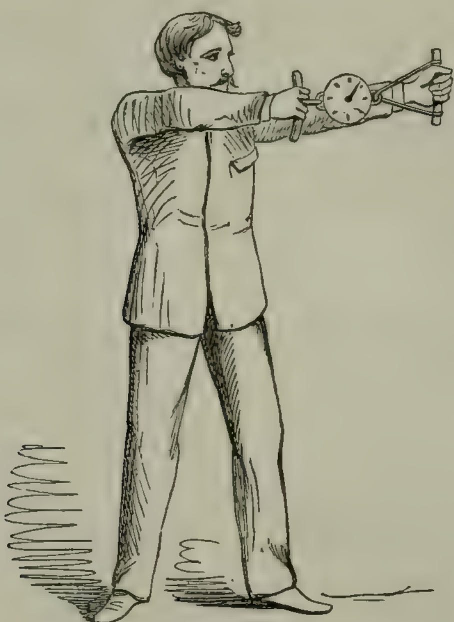
Place of Birth ____________ *Occupation* ____________

Race ____________ *Origin* ____________

Name and Address of Observer ________________________

Girth of Chest.—This is the method adopted in the British Army. Make the person stand quite upright, with his shoulders back, and his arms hanging loosely by his side. The measurement must be taken next to the skin, without compressing it. The lower edge of the tape should touch the nipples, and the measurement should be read off in front. Care should be taken that the tape passes horizontally round the chest, because if the measurement is made obliquely, below the blade-bone, it will be erroneous. The person should be required to count ten slowly during the operation, to prevent him from keeping his lungs over-inflated. (If this measurement is made on females, it should be taken *below* the breasts.)

Strength of Arm.—It is proposed to measure the force that can be exerted by the arm when pulling (as an archer with a bow). A spring balance should be used for this purpose. The right or left arm, whichever is the strongest, should be used to draw, and the other to resist. The resisting arm must be free, and extended straight from the side, as nearly as possible in the line of the shoulders, and the hand of the other arm brought back towards the ear. (A spring balance, or 'arm-testing machine' for testing the drawing power, can be obtained of Herbert & Sons, 6 West Smithfield, London, E.C., price 18*s.* 6*d.*)



The above figure represents the position in which the strength of arm should be tested.

Appendix B.

Table XXVI., showing the Stature, Chest-girth, and Weight of Recruits, is introduced here for future reference and comparison. The figures show that recruits of the age of 18 years may be expected to increase 1 inch in stature, $1\frac{1}{2}$ inch in chest-girth, and 10 lbs. in weight, before they reach the age of 23 years.

TABLE XXVI.—STATURE (barefoot) of Recruits for the Army, 1860–4.

Height without shoes. Inches	Age last Birthday								
	17	18	19	20	21	22	23	24	25
72 and upwards	2	19	55	52	52	46	49	59	120
71–	2	71	123	113	129	101	102	124	240
70–	3	205	259	280	276	261	199	253	527
69–	21	519	555	559	508	488	400	455	747
68–	67	1172	1139	988	835	756	609	746	1135
67–	219	2995	2159	1706	1268	1108	877	964	1425
66–	871	5593	3277	2292	1428	1309	964	1019	1349
65–	1224	5009	2504	1814	1144	881	608	567	996
64–	753	3968	1344	1172	718	603	373	421	850
63–	386	534	232	358	123	105	63	65	134
and under 62	135	78	25	26	17	9	7	7	12
Total	3683	20,163	11,672	9360	6493	5667	4251	4680	7537
Mean	65·50	66·00	66·25	66·50	66·75	67·00	67·00	67·00	67·00

CHEST-GIRTH (empty) of Recruits for the Army Anthropometric Committee.

Chest-girth, empty. Inches	Age last Birthday								
	17	18	19	20	21	22	23	24	25
43–	—	—	—	—	—	—	—	1	—
42–	—	—	—	—	—	—	—	—	—
41–	—	—	—	—	1	—	—	1	2
40–	—	—	—	—	—	—	—	1	2
39–	—	—	2	5	1	2	3	4	2
38–	—	3	4	9	9	8	9	13	5
37–	2	8	12	13	19	14	18	22	16
36–	—	37	70	51	46	32	24	45	31
35–	3	74	123	80	51	63	38	43	41
34–	10	155	173	123	79	39	33	47	44
33–	26	166	131	63	23	20	11	13	16
32–	9	55	37	14	1	4	2	1	3
31–	7	11	9	2	—	—	—	—	—
30–	2	5	—	1	—	—	—	—	1
29–	1	2	—	—	—	—	—	—	1
Total	60	516	561	361	230	182	138	191	164
Mean	33·5	34·0	34·5	34·75	35·0	35·5	35·5	35·5	35·5

WEIGHT (naked) of Recruits for the Army, 1860–4.

Weight without clothes. lbs.	Age last Birthday								
	17	18	19	20	21	22	23	24	25
170–	4	39	69	101	116	145	160	177	180
160–	25	202	331	441	472	489	484	528	489
150–	75	871	1228	1396	1409	1369	1199	1317	1218
140–	338	3674	4055	3950	3411	3024	2537	2497	2290
130–	1345	9965	8881	7128	5073	3981	3153	2914	2590
120–	2724	18,196	11,765	7497	4391	3351	2206	2266	2132
110–	3494	13,912	5961	2937	1695	1191	761	757	751
100–	1404	2734	985	374	151	116	50	70	107
under 100	146	282	50	19	5	2	1	1	3
Total	9555	49,875	33,325	23,843	16,723	13,672	10,559	10,527	9760
Mean	120·0	125·0	125·0	130·0	135·0	135·0	135·0	135·0	135·0

Appendix C.

Index to the Tables in the several Reports of the Committee, showing the nature of the measurements given in each Table.

In 1879.

Several selected classes; males at each age.	Stature, weight, and ratio of weight to height.
Christ's Hospital School; males at each age.	Stature, weight, chest-girth, and relation to one another, by Sir Rawson Rawson.
British Race in England and America, and Belgians; males and females, at each age.	Stature and weight, with diagrams, by C. Roberts.
Recruits, British and American armies, at each age.	Stature and weight, by C. Roberts.

In 1880.

Schoolboys of several classes, of age 11 to 12.	Stature, by C. Roberts.
Standard class; males of ages 10 to 50.	Stature, weight, chest-girth, and strength of arm, with diagram.
Standard class; males of ages 10 to 50.	Relation of the several measurements to one another.
Standard class; males of ages 10 to 50.	Mean annual growth.
Professional classes; males of ages 10 to 50	Colour of eyes and hair, with diagram.
Persons of town and country origin; males at each age.	Stature and weight.
American boys and girls.	Stature and annual growth, with diagrams, by Prof. Bowditch and Sir Rawson Rawson.
Factory children; boys and girls, 1833, 1871–3.	Stature and weight, by C. Roberts.
Marlborough College; males at each age.	Stature, weight, chest-girth, girth of head, arm, and leg, by the Rev. T. A. Preston, Sir Rawson Rawson and C. Roberts.
Telegraph messengers; youths at each age.	Weight, chest-girth, and lifting power, by G. C. Steet.

In 1881.

General population of United Kingdom; males at each age.	Increase in stature, weight, chest-girth, and strength of arm, with diagram.
General population of United Kingdom; males at each age.	Stature, weight, chest-girth, and strength of arm.
Population of different classes; males at each age.	Stature and weight.
Population of different classes; males from 25 to 50.	Relative stature.
Population of different classes; males at each age.	On calculation of deciles, quartiles and medians applied to range of stature, weight, and strength of arm, by F. Galton.
Population of different classes; males at different ages.	On army test of eyesight in each class, with diagram, by Inspector-Gen. Lawson.
Marlborough College; boys at each age.	On Snellen's tests for eyesight, near and distant vision, and colour-blindness, by the Rev. T. A. Preston and C. Roberts.

In 1883.

1. General population of each part of United Kingdom; adult males.	Stature, weight, chest-girth, and strength.
2. General population; adult males and females.	Relative stature, weight and strength.
3. Population of counties; adult males.	Stature, weight, and complexion, with diagram and five maps.
4. Population of counties; adult males.	Stature: ratio per 1,000.
5. Population of several countries, Europe and America; adult males.	Stature: average, medium, and extreme.
6. Population of several races and nationalities; adult males.	Stature.
7. Selected classes (British); adult males.	Stature and weight.
8. Criminals and lunatics (British) compared with other classes; adult males.	Stature and weight.
9. Criminals and lunatics (British) compared with other classes; adult males.	Complexion: colour of eyes and hair.
10. Population of counties of United Kingdom; adult males.	Complexion: degree of nigrescence.
11. Population of English and Welsh origin; males and females at each age.	Complexion.
12. Classification of population according to media.	Nurture, occupations, and sanitary surroundings.
13. Schoolboys of several classes, of age 11 to 12.	Stature (same Table as in 1880).
14. Population of several classes; males from 25 to 30.	Relative stature (same Table as in 1881).
15. Infants (at birth); males and females	Height, length, and weight.
16. Population of several classes; males at each age.	Stature.
17. Population of several classes; females at each age.	Stature.
18. Population of several classes; males at each age.	Weight.
19. Population of several classes; females at each age.	Weight.
20. General population; males and females at each age.	Stature, weight, chest-girth, strength, and span of arm; relation to each other, and between the sexes.
21. Industrial Schools; males and females at each age.	Stature, weight, chest-girth, and span of arms.
22. Industrial Schools; males and females at each age.	Complexion.
23. Swinton Industrial School; males and females at each age.	Stature, weight, chest-girth, breathing capacity, strength of arm, sight, and complexion.
24. Factory children, 1833–73; males and females at each age.	Stature and weight.
25. York Friends' School, 1853–79; males at each age.	Stature and weight.
26. Recruits (British army), 1860–64; ages 17 to 25.	Stature, weight, and chest-girth.

List of recent Monographs on the subject of Anthropometry published in England and the United States.

Gould, B.A. . .	Investigations in the Military and Anthropological Statistics of American Soldiers. *United States Sanitary Commission Memoirs*, New York, 1869.
Beddoe, J. (M.D.) .	On the Stature and Bulk of Men in the British Isles. *Mem. Anthrop. Soc.* vol. iii., London, 1869.
,,	Notes and Queries on Anthropology for the use of travellers and residents in uncivilised lands. *Drawn up by a Committee appointed by the Brit. Assoc.*, 1874.
Fergus, Dr. W., Rodwell, G. F., and Preston, Rev. T. A.	A Series of Measurements made at Marlborough College. *Jour. Anthrop. Inst.*, 1874.—A continuation of these measurements, together with observations on eyesight and colour-blindness, made annually to the present time by The Rev. T. A. Preston, in the *Report of the Marlborough College Natural History Society.*
Galton, F. . .	On the Height and Weight of Boys, aged 14 years, in town and country Public Schools. *Jour. Anthrop. Inst.*, 1875.
Human Faculty, London, 1883.	Contains a List of Papers on Anthropometric subjects contributed to various scientific journals and literary magazines by the author.
Baxter, J. H. (M.D.)	Statistics, Medical and Anthropological. *Report of the Provost-Marshal-General's Bureau, U.S. Government*, Washington, 1875.
Roberts, C. . .	The Physical Development and Proportions of the Human Body. *St. George's Hospital Reports*, 1874–6.
,, . .	The Physical Requirements of Factory Children. *Jour. Statistical Soc.*, 1876.
,, . .	A Manual of Anthropometry. London, 1878.
,, . .	The Detection of Colour-blindness and Imperfect Eyesight, *drawn up for the use of the Anthropometric Committee.* London (Bogue, St. Martin's Place), 1880.
Bowditch, H. P. (M.D.)	The Growth of Children. *Eighth Annual Report State Board of Health, Mass., U.S.*, Boston, 1877.
,,	A Supplementary Investigation. *Ibid.*, 1879.
Peckham, G. W. (M.D.)	Milwaukee, The Growth of Children. *Sixth Annual Report of the State Board of Health*, Wis., U.S., 1882.

Report of the Committee, consisting of General PITT-RIVERS, Dr. BEDDOE, Mr. BRABROOK, Professor FLOWER, Mr. F. GALTON, Dr. GARSON, Mr. J. PARK HARRISON (*Secretary*), Dr. MUIRHEAD, Mr. F. W. RUDLER, *and* Professor THANE, *appointed for the purpose of Defining the Facial Characteristics of the Races and Principal Crosses in the British Isles, and obtaining Illustrative Photographs.*

OWING to the comparative scarcity of skulls and other remains of the earlier inhabitants of the British Islands, and the imperfect condition of many of them owing to lapse of time, more difficulty has been experienced in completing the identification of the Long-barrow type than occurred in the case of the Round-barrow and Saxon types (B and C),

the features of which were defined in the Report of 1882. There appears, however, to be little doubt that the short dark type, which, as the Committee mentioned last year, certainly exists in the population at the present time, and which offers a marked contrast to the other types, accords in stature, lightness of frame, narrowness of skull, and fine osseous features generally, with the skeleton remains found in the majority of the early barrows. The Committee, therefore, have no difficulty in considering it as the main Type A; and its characteristic features have, consequently, been inserted in the annexed table, for comparison with Types B and C. The question whether there was a second pre-Celtic race in this country is hardly ripe for discussion; but it is receiving the special attention of several members of the Committee.

Table in which the typical features of the Three Principal Races in the British Isles are compared.

	Features	A	B	C
a	Forehead	Vertical, square	Receding	Vertical, rounded
b	Supra-orbital ridges	Oblique[1]	Prominent, continuous across brows	Smooth
c	Cheeks	Tapering to chin	Long	Wide, full
d	Nose	Straight, long	High-bridged, projecting	Short, bulbed
e	Mouth	Lips thick, unformed	Lips thin, straight, long	Lips well-formed
f	Chin	Small, fine	Pointed, projecting	Heavy, rounded
g	Ears	Rounded, lobed	Pear-shaped, channelled lobules	Oval, with full lobes
h	Jaw	Narrow	Large, square	Heavy, wide
i	Eyes	Dark	Blue-grey, sunk	Blue, prominent
j	Hair	Very dark, crisp, curling	Light-brown, slightly waved	Light, limp
	Skull	Dolichocephalic	Sub-Brachycephalic	Sub-Dolichocephalic
	Average height	5 feet 3 inches (m. 1·600)	5 feet 9 inches (m. 1·753)	5 feet 7 inches (m. 1·702)
	Habit	Slight	Bony, muscular	Stout, well-covered

This table represents, as nearly as the present state of our knowledge permits, three main types in this country.

In the mass of the population one or other set of features is found to predominate. The prevalent type differs in different localities; and the principal cause of the difference appears to be ancestral.

Progress has been made in the identification of several sub-types, especially the Gaels, Picts, Angles, and Jutes. But the definitions are not at present complete. The Committee trust that, whenever ancient remains are discovered which there may be reason to believe belong to the above people, or to the Long-barrow race, they may be carefully preserved, and information forwarded to the Secretary. The long bones, which are often put away, are specially required for the purpose of ascertaining

[1] In place of 'prominent brows,' as in the report for 1882.

stature. They request also to be informed of the existence of any skulls in local museums or private collections, that would assist in the identification of the above types.

Negatives have been taken of very pure examples of the Cymric race in North Wales, and several photographs have been purchased. The expenditure has amounted to 4*l.* The Committee ask to be reappointed, and that the grant voted last year be renewed.

Report of the Committee, consisting of Mr. JAMES GLAISHER (*Secretary*), *the* Rev. Canon TRISTRAM, *and the* Rev. F. LAWRENCE, *for promoting the Survey of Eastern Palestine.*

1. The Committee of the Palestine Exploration Fund have been endeavouring during the last year to obtain from the Sultan the firman granting permission for the prosecution of the Survey of Eastern Palestine.

2. Their efforts, aided by the personal influence of Lord Dufferin, have hitherto proved ineffectual. They have therefore decided on taking up another branch of their original prospectus, and will proceed at once with the Geological Survey of Palestine.

3. A great deal of geological work has been done in the country by individual travellers, but up to the present time there has been no expedition specially organised for the purpose of effecting a complete geological survey.

4. The valley of the Jordan and the basin of the Dead Sea have been examined by Mr. Lartet, whose work on the subject appeared in the year 1864; and by Dr. Fraas, whose report was published in 1867. Papers on the geology of Palestine by English travellers have also appeared in the quarterly journal of the Geological Society, and elsewhere, by Messrs. Duncan, Carter, Holland, Bauerman, Huddleston, and Milne. The Rev. Canon Tristram and Captain Conder have also furnished a large quantity of notes and information on the subject.

5. The Committee of the Exploration Society have been fortunate in securing the services of Professor Hull, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Ireland, for this important work. He proposes to start about the middle of October, accompanied by his son, Dr. E. G. Hull, as medical adviser, and to proceed to examine the country from the south, namely, the Wady Arabah, which runs northward from Akabah to the southern shores of the Dead Sea. Here a base is found in the granites of the Sinai Peninsula. It will also be desirable to penetrate into Moab, along the border of which country the Nubian Sandstone comes to the surface; and most important data, bearing on the geological problems, may here be expected. After examining the Wady Arabah and the border of Moab the party will proceed, by the route which will appear to Professor Hull most convenient, to make the geological reconnaissance of Western Palestine.

6. The expedition will be strengthened by the presence and experience of Captain Kitchener, R.E., formerly one of the officers of the survey of Western Palestine. Perhaps Lieut. Mantell, R.E., will also be able to join the party. During the geological operations, the engineers will be instructed to clear up certain points of interest which lie about that part of the country. Thus, they will examine the eastern end of the Tîh Desert, and the passes leading up to the plateau, so as to determine the best route for a large body of people travelling northwards from Sinai: they will explore the topographical features of the Arabah east and west, and the southern edge of the Negeb so as to ascertain the passes from the Tîh plateau to the first terrace: they will examine the sites of Ezion-geber, Elath, Kadesh, and the way of the spies; look for the road or roads by which communication was kept up between Jerusalem and Ezion-geber, the posts on the old Roman road; and throw light, if possible, on the question whether the Israelites did not go over to Arabia Proper instead of remaining, as is generally supposed, in the Tîh Desert. It is expected that the expedition will accomplish its objects in about four months. The cost of the whole, including publication of results, is estimated under 2,000*l.*

Report of the Committee, consisting of Mr. JAMES HEYWOOD, Mr. WILLIAM SHAEN, Mr. STEPHEN BOURNE, Mr. ROBERT WILKINSON, *the* Rev. W. DELANY, Professor N. STORY MASKELYNE, Dr. SILVANUS P. THOMPSON, Miss LYDIA E. BECKER, Sir JOHN LUBBOCK, Professor A. W. WILLIAMSON, Mrs. AUGUSTA WEBSTER, Dr. H. W. CROSSKEY, Professor ROSCOE, Professor G. CAREY FOSTER, *and* Dr. J. H. GLADSTONE (*Secretary*), *appointed to watch and report on the workings of the proposed revised New Code, and of other legislation affecting the teaching of Science in Elementary Schools.*

AT the close of their report last year, your Committee stated that, if reappointed, they proposed to obtain information upon certain points connected with the working of the New Code, and to draw the attention of the Council to any matter that may be necessary in connection with the working of the Code, or in respect of any future alterations.

Nothing has occurred during the past twelvemonth which seemed to require the action of the Council; and as the reports of Her Majesty's Inspectors on the schools that have already been examined under the New Code are only beginning to be issued, it seems premature to come to any definite conclusion as to its working.

Two official documents, however, appeared last summer bearing upon the question of Science teaching in Elementary Schools:—'The New Regulations for Her Majesty's Inspectors,' dated August 9, and the Circular on 'Higher Board Schools in Wales,' dated August 10, 1882.

The first is a very important document, as it indicates the intentions of the Education Department in regard to carrying out the provisions of

the New Code; and some of these instructions have a bearing upon the matters referred to this Committee. In paragraph 5 it is laid down that where scholars of Standard I. are taught in the Infant department 'the course of lessons should include simple recitation and lessons in geography or elementary science to correspond to the class subjects intended to be taken up in the boys' or girls' school.' Paragraph 20 runs thus: 'In teaching geography, good maps, both of the county and of the parish or immediate neighbourhood in which the school is situated, should be affixed to the walls, and the exact distances of a few near and familiar places should be known. It is useful to mark on the floor of the school-room the meridian line, in order that the points of the compass should be known in relation to the school itself, as well as on a map.' Paragraph 28 is as follows: 'In cases in which it is proposed to teach specific subjects, it will be desirable for you to ascertain that the teacher has given proof of his fitness to teach them by having acquitted himself creditably at a training college, or at some other public examination. You will often find that these subjects are most thoroughly taught when a special teacher is engaged by a group of schools to give instruction in such subjects once or twice a week, his teaching being supplemented in the intervals by the teachers of the school. You will judge of all schemes of elementary science which may be submitted to you for approval by their applicability to the school stay of the bulk of scholars, remembering that the whole course of study is primarily designed for those children who go to labour after they have reached the full-time standard.' The allusion to the engagement of a special teacher for a group of schools evidently points to the practice at Liverpool and Birmingham. The merit grant being an important part of the New Code, their Lordships describe, in paragraph 32, what they consider necessary in order that a school should be assessed as 'excellent.' *Inter alia*, they lay it down that 'if higher subjects are attempted, the lessons are not confined to memory work and to the learning of technical terms, but are designed to give a clear knowledge of facts, and to train the learner in the practice of thinking and observing;' and also, 'where circumstances permit it has . . . . an orderly collection of simple objects and apparatus adapted to illustrate the school lessons, and formed in part by the co-operation of the scholars themselves.'

The second document, while speaking of the accommodation required in these 'Higher Board Schools in Wales,' states that 'as the provision of a rather larger number of class-rooms than are necessary for an ordinary elementary school, and the establishment of one or more laboratories for practical instruction in chemistry, or branches of physical science which have a bearing on the industries of the district, may require the premises of the new school to be of a somewhat more expensive character than usual, their Lordships will feel themselves justified in relaxing the rule which limits the amount of the loan, which they are willing to recommend, to 10*l.* per scholar accommodated.'

All these regulations are quite in accordance with the opinions and desires of your Committee.

Several Divisional Conferences were held last Easter with the leading Inspectors, and the Lords of the Committee of Council on Education have just communicated the conclusions at which they have arrived on some of the more important questions discussed at those meetings. They are contained in a 'Circular of Instructions to Her Majesty's Inspectors as to

Uniformity in Administration of the New Code,' bearing date August 6, 1883. The references to the teaching of natural knowledge are as follows:—

'*Infant schools or classes.*—In order to satisfy fully the requirements of Art. 106 *b* 2, the mistress early in the school year should draw up, and enter in the Log Book, a course of thirty or forty collective lessons, *e.g.*, on animals; on such objects as coal, glass, and salt; on common employments, as paper-making, cotton mill, house-building, one of the trades of the district being chosen in preference; on form and colour, food, plants, and clothing; on simple facts in nature, as rain, frost, the seasons; on familiar scenes in common life, as the post-office, a shop, a railway, washing, or harvest. Each of these should in the course of the year be given two or three times, and on the day of inspection the Inspector may select one or two lessons to be given by the teacher in charge of the class; then, at the point of the lesson where questioning begins, he may himself intervene, and ascertain how far the lesson has had intelligent effect.

'It is desirable to recommend teachers (especially assistants and pupil-teachers) to preserve in a book the notes of such lessons for future expansion and reference.

'*Class subjects.*—The following variations are allowable in the second class subject.

'(i.) Elementary science in lower division (Standards I.–III. or I.–IV.) and geography in upper (Standards IV.–VII. or V.–VII.).

'(ii.) Geography or elementary science in Standards I.–IV. and history in V.–VII.

'The course of object and elementary science lessons in the lower standards should, when possible, be preparatory to the specific subject—if any—intended to be taken up in the Fifth Standard.

'*Specific subjects.*—Any Inspector who desires aid in the examination of a specific subject with which he is not acquainted should apply to the senior Inspector of his Division.'

The only matter arising out of the working of the New Code which your Committee feel justified in bringing forward at present, is the provision which is being made by the larger Boards for the extended teaching of natural knowledge. Special reports have been drawn up as to these arrangements in London, Manchester, Birmingham, Sheffield, and Liverpool, and are given in the Appendix.

Your Committee would draw attention to two or three points. 1. The largely extended meaning given to object lessons, and the endeavour to supplant the unintelligent and dry teaching which has often of late years passed under that name. 2. The appearance of systematic schemes of elementary science as a class subject. 3. The methods by which the scientific specific subjects are taught at Liverpool and Birmingham. 4. The increased attention paid to science in the pupil-teachers' centres, which are now being established in the large towns. This point is considered as one of special importance, inasmuch as the pupil-teachers are now generally expected to give object lessons in the Infant schools, and perhaps elementary science lessons in the boys' and girls' departments; while at the same time there is no provision made in Schedule V. for securing their getting any instruction whatever in the rudiments of natural knowledge. It is true that marks are given to any candidate for admission to the training colleges who passes successfully in one of eight scientific subjects recognised by the Science and Art Department; but this fails to

meet the case in two respects; first—that it does not ensure that every pupil-teacher shall take up science at all; in fact, according to the last report of the Committee of Council on Education, out of 2,061 male candidates only 597, and out of 3,541 female candidates only 166, received credit for scientific knowledge; second—even as to these it does not follow that they have such a general knowledge of nature as shall be of much practical use, seeing they took up certain specialised sciences. The only subject of wide range is Physiography; and this was taken by only 126 males and 24 females.

APPENDIX.

London.

Since the passing of the New Code of 1882 the London Board have revised their arrangements for the teaching of natural science in their schools. A new circular has been sent out containing instructions to teachers relative to object lessons and elementary science, laying down a broad scheme of instruction both in the Infant department and in Standards I. to VII., from which the teachers may choose any course they may feel themselves most qualified to take.

It is required that each teacher shall adopt a scheme of 'Elementary Science' in the form prescribed by the Code of 'a progressive course of simple lessons adapted to cultivate habits of exact observation, statement, and reasoning;' but it is not obligatory upon the teacher to take this as the second-class subject under the Code for examination by Her Majesty's Inspector. A model scheme, fuller than that in Schedule II. of the Code, is suggested; but teachers are informed that they have full liberty to vary it according to their tastes and acquirements.

The scheme is as follows:—

Standard I.	Standard II.	Standard III.	Standard IV.	Standard V.	Standard VI.	Standard VII.
Extension of the Object Lessons in the Infant School, with simple illustrative experiments.	Comparison of different plants or animals. Ordinary phenomena of the earth and atmosphere. Substances of domestic use.	Simple principles of classification of plants and animals. Further phenomena of the earth and atmosphere. Substances used in the Arts and Manufactures.	More complete classification of plants and animals, with typical examples. The three forms of matter familiarly illustrated.	(*a*) Animal and plant life, with the most useful products; or, (*b*) More definite notions of matter and force illustrated by simple machinery or apparatus.	(*a*) Animal and plant life, with special reference to the laws of health; or, (*b*) The commonest elements and their compounds. The mechanical powers.	(*a*) Distribution of plants and animals, and the races of mankind; or, (*b*) Light, heat, and electricity, and their applications.

Teachers are encouraged to form collections of objects to illustrate their lessons, with the co-operation of the scholars, and if the collection is sufficiently large, a cabinet to contain the specimens is sent to the school.

The London Board has not taken into consideration any definite plan as to the scientific specific subjects of Schedule IV.

The Board, however, now gives instruction to its pupil-teachers at certain centres, and has made provision for the imparting of a knowledge of nature at each of these. The course of instruction is divided into four stages. The first stage begins with Huxley's 'Introductory Primer' as a general guide, and treats of general principles of natural knowledge, the general properties of liquids and gases, and the leading characteristics of plants and animals. The second stage deals with the properties of solid bodies, the chemical notions of elements and compounds, the mechanical powers, and the characteristics of the principal divisions of the animal and vegetable kingdoms. The third stage includes the elementary stage of Physiography, according to the syllabus of the Science and Art Department, as far as the subjects have not been included in the previous instruction, or under the head of geography; such as the crust of the earth, the sea, the atmosphere, the physical forces, and a general idea of the animal body. The fourth stage includes the advanced stage of Physiography, as defined by the Science and Art Department, and the application of the various sciences already studied—mechanics, electricity, physiology—to the arts of life. As this course extends over a large range of subjects, it is understood that none of them should be treated very fully, but that the information given should be accurate as far as it goes, and the theoretical conceptions clear. The lessons should of course be illustrated either by the natural objects themselves, or, where that is not possible, by diagrams. This course has scarcely got into full operation this season; but an examination of the pupil-teachers was held last July by the Board's inspectors.

Manchester.

Under the Manchester School Board science is taught both in the Higher Grade Board Schools, and in the ordinary Day schools.

I. In Higher Grade Schools. In four schools—viz., Peter Street, Ducie Avenue, St. Matthew's Ardwick, and Upper Jackson Street—science lessons form part of the ordinary day school work; in two others some of the more advanced boys and girls come for one hour in the evening for similar instruction. The subjects taught are—Mathematics; Physiology; Inorganic Chemistry, Theoretical and Practical; Organic Chemistry; Sound, Light, and Heat; Magnetism and Electricity; Physiography; and Theoretical Mechanics. Some of these subjects are taught in one school, and some in another. Practical Chemistry has hitherto been taught only at Peter Street, but now the Board have erected chemical laboratories at Ducie Avenue and St. Matthew's, Ardwick, and that subject will be taught practically at those two schools also this next winter. The teaching of these subjects at the aforenamed schools is under the Science and Art Department. Last May there were 727 passes.

II. In ordinary Day schools. In some schools Botany, Mechanics, or Physiology are taken as specific subjects; and simple lessons on these sciences are given in the same schools as a kind of introduction to the work of the upper classes. Algebra and Euclid are taken as specific subjects in several schools. Object lessons are given not only in the Infant schools, but also in Upper schools in accordance with the work of the standard in the Code.

Sheffield.

Extract from a letter of Mr. John F. Moss, Clerk of the Sheffield School Board:—

'Object lessons form part of the course of instruction in all the schools of the Board, and in addition to the ordinary small collections we have a few simple appliances, geological specimens, &c., got together by teachers and scholars. But "Elementary science" is not yet very extensively taken up as a class subject, and we have no visiting lecturers on science. At the Central schools, however, Chemistry, Machine Construction, &c., are taught to large classes with very marked success. . . . The scholars are drafted from the other public elementary schools of the town, and we have a good laboratory, suitable apparatus, &c. Specially qualified teachers are engaged in this department of the work.

'Besides, we have a workshop in which the upper class boys are taught the use of tools. They make models in wood and iron, requiring accuracy of measurement and nicety of manipulation. They also do other practical exercises under the direction of a skilled workman and the science master.'

Liverpool.

Extract from a letter of Mr. E. M. Hance, Clerk of the Liverpool School Board:—

'For Standards V.–VII. we carry on the instruction in "Mechanics," a subject which, in the manner it is treated here, is almost equivalent to "Elementary Physics," previously given in Standards IV.–VI.[1] For Standard IV. we are having a preliminary course in the "first stage" of the subject. In the lower standards we are about to commence, in connection with the class-subject Geography, a systematic course of instruction in the simpler truths of Physical Geography. Mr. Hewitt, the Board's Science Instructor, is on the point of giving a course of illustrative lectures to the Board's teachers (Head and Assistant) as to the best mode of demonstrating those truths by experiment; and it is intended to supply each teacher with a simple collection of apparatus. For the Infants' Schools, Mr. Hewitt is preparing, and expects to have ready at least the first part by the end of next month, a series of object lessons upon things or phenomena of which the children have experience in their daily life, and near their own homes. The series is designed to prepare the way for, and to lead up to, the instruction given in the lower standards.'

Birmingham.

Systematic instruction in Elementary Science has been introduced into all the schools connected with the Birmingham School Board, and the results have proved as remarkable as they are satisfactory.

The staff consists of a Science Demonstrator, with two assistant demonstrators.

A Laboratory has been built at the Icknield Street Schools, and well furnished with scientific appliances.

The Science Demonstrator and his assistants are employed in visiting each school in rotation, and giving lessons, which are thoroughly well illustrated by apparatus and experiments.

[1] An account of this system of instruction is to be found in the Report of the meeting at Sheffield in 1879, p. 477.

The experiments are carefully prepared in the Laboratory, and a hand-cart specially fitted up for the purpose conveys the apparatus necessary for their performance from school to school.

The lessons are given in both the girls' and boys' departments to the children in Standard V. and upwards, and one of the school teachers is always present. Between the visits of the demonstrators (which are at present fortnightly) at least one lesson on the same subject is given by the teacher of the class. In this the matter of the demonstrator's lesson is recapitulated and expanded, and such new points are taken up as may be necessary for the completion of the instruction in the subject. An examination on paper is also held fortnightly, during the time allowed for composition and dictation, the answers being laid before the Science Demonstrator at his next visit.

The subjects taught have been Elementary Mechanics and Electricity to the boys; Domestic Economy and Physiology to the girls. Lessons are now being given to about 1,500 boys and 1,000 girls in twenty-nine schools; and with the increase of the schools, the system will doubtless be extended by the Board. The plan framed does not, it must be observed, give scientific instruction in a few special schools, but *provides it in all schools under the Board as a part of the regular work of the school.*

In schools situated in the poorer localities—for which the charge made for the whole work of the school is only one penny per week—the science instruction is as carefully given as in the others, and secures the intensest interest and attention of the scholars.

Classes in connection with the Science and Art Department are also established for pupil teachers in the service of the Board.

Tested by experience, the success of the scheme may be regarded as thoroughly established.

The introduction of scientific instruction has added new life to the general work of the schools. The intellectual interest of the scholars has been aroused, and the papers on the ordinary subjects of elementary education have become more numerous. A school which passes a good examination in science is found, as a matter of fact, to pass a better examination than ever before in writing, reading, and arithmetic.

Experiments being performed in the sight of the scholars, and apparatus being actually shown to them, the instruction does not in the slightest degree partake of the nature of 'cram.'

Special examinations have been conducted by an independent examiner —Professor Poynting, of the Mason Science College—and that gentleman has reported to the Board, with great satisfaction, that the answers to the questions set have been characterised by intelligent thought. The actual report made is worth quoting, as a sufficient reply to those who fear lest the introduction of science should mean the increase of mere mechanical 'cram.'

'Hardly any of the questions in my paper could have been answered without independent thought on the part of the candidates, and I had very few answers showing a want of such thought. The boys showed that they had seen and understood the experiments which they described —that they had been taught to reason for themselves upon them—and that they were not merely using forms of words which they had learnt without attaching physical ideas to them.'

The system described is economical as well as effective. The apparatus being carried from school to school, the great expense of providing a set

of good apparatus for each school is saved. In the central laboratory the work for all the sixty-two departments in which lessons are given is prepared.

The chief demonstrator is paid 300*l.*; the first assistant 150*l.*; and second assistant 110*l.*; while two juniors receive 10*s.* and 12*s.* per week.

The cost of the apparatus has been about 250*l.* or 300*l.*

It would be quite possible for a number of schools in country districts to join together and secure the same advantage at a trifling cost to each.

The essential parts of the system are: (1) the employment of thoroughly scientific men to give experimental demonstrations, and, (2) the introduction of elementary science as a regular course of instruction.

In order to prepare the way for the Science Teaching in the upper standards, the teachers of the infants' schools and of the lower standards in the upper schools are instructed to make their object lessons systematic, although of course divesting them of technicality. A series of suggestions for systematic object lessons has been prepared by the Science Demonstrator and circulated among the teachers, so that the scholars may be gradually led to the work of the upper standards.

Report of the Committee, consisting of Sir FREDERICK BRAMWELL (*Secretary*), Dr. A. W. WILLIAMSON, Professor Sir WILLIAM THOMSON, Mr. ST. JOHN VINCENT DAY, Sir WILLIAM SIEMENS, Mr. C. W. MERRIFIELD, Dr. NEILSON HANCOCK, Sir FREDERICK ABEL, Captain DOUGLAS GALTON, Mr. E. H. CARBUTT, Mr. MACRORY, Mr. H. TRUEMAN WOOD, Mr. W. H. BARLOW, *and* Mr. A. T. ATCHISON, *appointed for the purpose of watching and reporting to the Council on Patent Legislation.*

THE fact that an Act for the reform of the Patent laws was passed in the Session just concluded, has of necessity thrown a good deal of work upon the Committee. It has met five times, and nearly every member of it was present at one or more of the meetings. The following gentlemen have been added:—Sir John Lubbock, Mr. Alfred Carpmael, Mr. R. E. Webster, Q.C., and Mr. Theodore Aston, Q.C.

Besides the Government Bill, which was introduced on February 19, the Bill prepared by the Society of Arts, and referred to in previous reports of this Committee (see British Association 'Report,' 1881, p. 222, and 1882, p. 310), was again introduced by Sir John Lubbock, and Mr. Anderson also introduced a Bill generally similar to those he has brought forward in former years. The last two Bills were read a second time, but were not further proceeded with. After the second reading of the Government Bill, it was referred to the Grand Committee on Trade, by which some alterations of a more or less important character were made. The final stages were run through rather rapidly, and, in one of the last weeks of the Session, it passed through the House of Lords. The speed with which, after the long delay in the earlier part of the Session, the Bill was carried through Parliament, rendered it by no means easy to obtain amendment in it, and indeed

the risk of the Bill not passing if many changes were introduced, afforded a reason to the President of the Board of Trade for not accepting many alterations pressed upon him from various quarters.

It does not appear desirable to lengthen this report by giving an abstract of the Bill, since its main provisions have already been published in the technical newspapers and elsewhere. An excellent summary is to be found in the Society of Arts 'Journal' for September 7, 1883.

The Committee felt that the Government Bill compared unfavourably with that of the Society of Arts, and this opinion was shared in many other quarters. Had the Government consented to accept that Bill, or had they, at all events, been willing to adopt certain of its provisions, the Committee believe that a much better measure would have resulted than they have any reason to hope the present Act will prove to be. On the whole, they are not sanguine as to any very beneficial results from the new law. The reduction of cost in the earlier stages of a patent has ensured the popularity of the Act in certain quarters, but it remains to be seen how far the actual process will be cheapened, and to what extent the new provisions for opposition, &c., will entail counterbalancing expenses. The substitution of a single working head, instead of *ex-officio* Commissioners, is an obvious advantage, but the reform has not gone nearly far enough, for the new 'Controller' is to be a mere departmental official, subordinate to several distinct authorities, instead of possessing independent power. The provisions for applications for patents contain some minor improvements. A British patent is no longer to be affected by the duration of a corresponding foreign patent. The practice of 'racing for the Seal,' trying to get a later application sealed before an earlier one, is abolished. The system proposed for the examination of specifications is incomplete, and will probably be found to be of slight value, while it is very likely to give considerable additional trouble to the inventor. The provisions for opposition appear most objectionable, and will certainly press very hardly on the poorer class of inventors. Those for amendment and disclaimer are improvements on the present system. That the jurisdiction of the Privy Council in the question of the extension of patents is preserved, appears to the Committee a matter for regret. The position of inventors as regards the Crown is somewhat improved, but it is manifestly unfair that the Treasury should be the tribunal to decide upon the terms on which the Crown may use inventions.

This Committee co-operated with the Patent Committee of the Society of Arts in endeavouring to improve the Bill, and, in order to bring their views before the Government, they sought interviews with the President of the Board of Trade, and with the Lord Chancellor; they believe their efforts have not been without good result. On both occasions time did not admit of their asking the sanction of the Council of the Association, and they therefore were obliged to go as a Committee merely, and not as representing the Association, or with the authority such sanction would have given, had it been obtained. Care was taken that this was definitely stated.

The Committee think it well that they should be reappointed for the purpose of watching and reporting upon the working of the new Act.

The Committee would be glad if they could be allowed a grant of 5*l.* to cover the various expenses, which otherwise (as in the past year) have to be defrayed by individual members.

Report of the Committee, consisting of Sir JOSEPH WHITWORTH, Sir WILLIAM SIEMENS, Sir FREDERICK BRAMWELL, Mr. A. STROH, Mr. BECK, Mr. W. H. PREECE, Mr. E. CROMPTON, Mr. E. RIGG, Mr. A. LE NEVE FOSTER, Mr. LATIMER CLARK, Mr. H. TRUEMAN WOOD (*Secretary*), Mr. BUCKNEY, *and* Sir WILLIAM THOMSON, *appointed for the purpose of determining a Gauge for the manufacture of the various small Screws used in Telegraphic and Electrical Apparatus, in Clockwork, and for other analogous purposes.*

THE Committee regret that it proved impossible for them to complete their report, recommending a series of screw threads, in time for the present meeting of the Association. They therefore content themselves with asking to be reappointed, in the hope that a little additional time will enable them to finish their work.

Report of the 'Local Scientific Societies' Committee, consisting of Mr. FRANCIS GALTON (*Chairman*), *the* Rev. Dr. CROSSKEY, Mr. C. E. DE RANCE, Mr. H. G. FORDHAM (*Secretary*), Mr. JOHN HOPKINSON, Mr. R. MELDOLA, Mr. A. RAMSAY, Professor SOLLAS, Mr. G. J. SYMONS, *and* Mr. W. WHITAKER, *appointed by the Council in compliance with the following resolution referred to the Council by the General Committee:*

> *That the Council be empowered to appoint a Committee, as recommended in their Report adopted by the General Committee on August 23, in order to draw up suggestions upon methods of more systematic observation and plans of operation for Local Societies, together with a more uniform mode of publication of the results of their work. It is recommended that this Committee should draw up a list of Local Societies which publish their proceedings.*

THE Committee have communicated with all the societies known to them which aeppar to fall under the designation of 'Local Scientific Societies which publish their proceedings,' giving to this definition a somewhat liberal interpretation, and they submit a tabular list of these societies with notes of their publications and other particulars. They are about 170 in number, and seem, from their rules and publications, to be centres whence local scientific information may conveniently be obtained.

The Local Societies differ widely in character. Those which are established in large towns, and are not particularly well situated for carrying on systematic local investigations, are often of high scientific rank, and their affairs are administered in a business-like manner by a regular staff. On the other hand, there are numerous smaller societies

and field clubs, scattered over the country, which are excellently situated for conducting local investigations, and are in many cases doing valuable work, but of which so little is generally known that it has often been difficult to discover their official addresses.

In some parts of the country the smaller societies either group themselves into what is practically a federation, or else affiliate themselves to some large society in their district, and the Committee think that if the Local Societies could more generally be induced to group themselves round what might be described as local sub-centres, it would not be difficult to devise methods of uniting the representatives of those sub-centres in the performance of interesting and important duties during the meetings of the British Association, with the final effect of establishing systematic local investigation throughout the country, and uniformity in the modes of publishing the results. The recommendations of the Committee will tend wholly in this direction, because, although they have considered many plans of fulfilling their instructions in a direct manner, no plan recommends itself to them as superior to this indirect method in its capacity for producing valuable and durable effects.

The Committee do not suggest any new topics for systematic investigation, but confine themselves to giving a few examples of what these topics are, taken from amongst those assigned to Committees of the Association during the past five years, and arranged in the order of the Sections that are severally concerned in them:—(A) Luminous meteors; Meteoric dust in various localities; Rainfall; Underground temperature: (C) Erosion of sea-coasts; Height of underground waters; Erratic blocks: (D) Photographs of typical races and crosses; Ancient earthworks; Prehistoric remains; Migration of birds at lighthouses and lightships; Periodical natural phenomena (flowering of plants, &c.); Injurious insects (their first appearance, &c.): (F) Anthropometric collections; Working of Education Code in Elementary Schools; Rudimentary Science in Schools: (G) Effective wind-pressure on buildings.

It can hardly be doubted that numerous systematic investigations of a local character will continue to be carried on, and that their successful prosecution would result in important gains to science. Neither does it appear doubtful that the successful prosecution of such investigations by the smaller Local Societies would be greatly encouraged and facilitated by the general interest shown in their work by the more influential societies in their neighbourhood, by a watchful oversight, a readiness to discuss and publish results, and by the personal influence of their leading members. The Committee offer the recommendations they are about to make in the trust that they will serve to remind the more important Local Societies of the high and useful function they are able to perform by entering into friendly and helpful relations with the small and scattered societies of their respective districts, and by offering themselves as their scientific representatives wherever representation may be necessary.

Believing that the British Association is fitted by its constitution and position to become an organising centre of local scientific work, and that through an extension of the system of delegation from Scientific Societies which has already been recognised in the Rules of the Association this object may be attained, the Committee venture to make the following proposals, thrown into the form of Rules, which, if approved, may be inserted amongst the Rules of the Association, with such amendments in the existing Rules as may be necessary in consequence.

'SUGGESTED NEW RULES.

'*Corresponding Societies.*

'(1). Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results of such investigations, especially if they are such as are carried on by Committees of the Association.

'(2). Application may be made by any Society to be placed on the list of Corresponding Societies. Applications must be addressed to the Secretary on or before the first of June preceding the annual meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

'(3). A Corresponding Societies Committee shall be appointed by the Council for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the Committee of Recommendations, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable, subject only to the conditions—(1) That the number of Societies on the list shall not exceed that which may be from time to time prescribed by the Council; (2) that the intended removal of any Society from the list shall not take effect until immediately before the commencement of the next annual meeting.

'(4). Every Corresponding Society shall transmit each year on or before the first of June, to the Secretary of the Association, a copy of its publications during the preceding twelve months, and shall at the same time return properly filled up a schedule, which will be issued by the Secretary of the Association, and which will contain a request for such information with regard to the Society as may be desirable.

'(5). There shall be inserted in the Annual Report of the Association a List, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

'(6). A Corresponding Society shall have the right to nominate any one of its members, who is also a member of the Association, as its Delegate to the annual meeting of the Association, who shall be for the time a member of the General Committee. The appointment of a Delegate to any annual meeting must be formally notified to the Secretary of the Association by the Secretary of the Corresponding Society not later than the first of July preceding that meeting.

'*Conference of Delegates of Corresponding Societies.*

'(7). The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually appointed by the Council, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

'The Conference of Delegates shall be summoned by the Secretary of the Association to hold one or more meetings during each annual meeting of the Association, and shall be empowered to invite any member or associate to take part in the meetings.

'The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

'It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations as brought before the Conference, in order that they and others who take part in the meetings may be able to bring the recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.'

The Committee believe that the distinction accorded to a Society through its selection and formal recognition by the British Association as one of its Corresponding Societies, the advantage of a widely-circulated notice of its local work in so important a volume as the Report of the British Association, and the honourable and useful duties assigned to its Delegate, would give considerable value to the title.

They also anticipate that a Society which had asked for and received recognition as a representative centre of the scientific institutions in its district, would be thereby stimulated to exercise that very creditable and important function with increased zeal and efficiency. The result would be to strengthen the mutual relations of the larger and the smaller Societies, to ensure the encouragement of any disposition to co-operate in systematic investigations, and to establish a practice of printing the scattered results obtained by the smaller Societies of any district in a consolidated form in the publications of their leading Society.

Finally, the Committee believe that the annual meetings of the proposed Conference of Delegates, under the chairmanship of a distinguished member of the Association, would have large influence in harmonising the action of their several Societies, without in any way tending to compromise their independence, and that they would offer a facility that does not now exist for the natural and healthy growth of a federation between remote Societies which have no more direct bond of union than through the British Association.

List of 'Local Scientific Societies which publish Proceedings.'

M.U. Midland Union of Natural History Societies. Y.N.U. Yorkshire Naturalists' Union.

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Aberdeen Natural History Society. 1862.	J. Roy, 33 Belvidere Street, Aberdeen.	54	5 0
Aberdeen Philosophical Society. 1840.	A. D. Milne, 58 Marischal Street, Aberdeen.	130	21 0
Alloa Society of Natural Science and Archæology. 1863.	Museum, Alloa	157	5 0 Ladies only
Arbroath Horticultural and Natural History Association. 1880.	Geo. Bell, Arbroath . . .	72	—
Banburyshire Natural History Society and Field Club. 1881.	E. A. Walford, 21 West Bar Street, Banbury.	80	—
Barnsley Naturalists' Society. 1867.	W. E. Brady, 1 Queen Street, Barnsley, Yorkshire.	90	2 0 1 0
Barrow Naturalists' Field Club and Literary and Scientific Association. 1876.	Cambridge Lecture Hall, Barrow-in-Furness.	130 (about)	—
Bath Microscopical Society. 1858.	R. H. Moore, 13 Pulteney Gardens, Bath.	44	21 0
Bath Natural History and Antiquarian Field Club. 1855.	Royal Literary and Scientific Institution, Bath.	81	5 0
Bedfordshire Natural History Society and Field Club. 1875.	T. G. Elger, Manor Cottage, Kempston, Bedford.	90	—
Belfast Natural History and Philosophical Society. 1821.	Museum, College Square North, Belfast.	155 (about)	—
Belfast Naturalists' Field Club. 1863.	W. Swanston, 50 King Street, Belfast.	280	—
Berkshire Archæological and Architectural Society. 1871.	J. Rutland, The Gables, Taplow, Maidenhead.	180	—
Berwickshire Naturalists' Club. 1831.	J. Hardy, Oldcambus, Cockburnspath, Berwickshire.	379	10 6
Birkenhead Literary and Scientific Society. 1857.	34 Hamilton Square, Birkenhead.	159	—
Birmingham Natural History and Microscopical Society. 1858.	Mason College, Birmingham .	382	—
Birmingham Philosophical Society. 1876.	Mason College, Birmingham .	154	—
Braintree and Bocking Microscopical and Natural History Club. 1880.	D. R. Sharpe, Bocking, Braintree.	89	—

Drawn up by H. George Fordham. (*Corrected to November*, 1883.)

Note.—'Number of members' includes all classes of members, and in some cases associates or students.

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. d.			
2 6	*Transactions*, 8vo., and separate papers.	Last vol. 1878 . .	Another vol. now being prepared.
10 6	*Proceedings*, 8vo. . .	Occasionally . . .	Now printing a selection of papers. Publications issued to members only.
5 0 Ordinary members only	*Proceedings*, 8vo. . . . *Annual Report*, 8vo. Separate papers, 8vo. . .	Last vol. 1876 . . Occasionally.	Museum.
2 6	*Flora of Arbroath and its Neighbourhood*, 16mo. 63 pp.	1882.	
5 0	*List of the Birds of the Banbury District*, 8vo. Separate papers, 8vo. . .	1882. Irregularly.	
6 0 3 0	*Quarterly Transactions*, 8vo., 12 pp.	1 vol. annually . .	Y.N.U.
10 6	*Annual Report and Proceedings*, 8vo.	Vol. iv. 1882–3.	
10 6	*Report*, 8vo. . . . . Presidential Address, and occasional papers.	Annually . . .	Library, and Cabinet of Slides.
10 0	*Proceedings*, 8vo. . . .	Since 1867, 4 vols., and vol. v., pt. 1.	
5 0	*Abstract of Proceedings and Transactions*, 8vo.	Since 1875, 3 pts. .	M.U.
21 0	*Report and Proceedings*, 8vo. .	Annually . . .	Museum and Library.
5 0	*Annual Reports and Proceedings*, 8vo.	Vol. i., New Series, 1873–80.	
10 0 2 6	*Transactions*, 8vo. . . . . *Annual Report*, 8vo.	Annually . . .	Library.
6 6	*Proceedings*, 8vo. . . .	1 pt. annually. 9 vols. and 1 no. issued.	
10 6	*Annual Report*, and President's Address.		
10 0	*Report and Transactions*, 8vo.	Since 1869, 4 vols., dated 1869, 70, 80, 81.	M.U. Library and Herbarium.
21 0	*Report of the Council*, 8vo. . *Proceedings*, 8vo. . . .	Annually . . . 1 pt. annually. Vol. iii., pt. 1, 1881–2.	M.U.
2 6	*Journal and Report*, 8vo. . .	Annually.	

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Brighton and Sussex Natural History Society. 1854.	J. C. Clark, 64 Middle Street, Brighton.	185	10 0
Bristol and Gloucestershire Archæological Society. 1876.	Rev. W. Bazeley, Matson Rectory, Gloucester.	518	10 6
Bristol Naturalists' Society. 1862.	A. Leipner, 47 Hampton Park, Redland, Bristol.	172	5 0
Buckingham, Architectural and Archæological Society for the County of. 1847.	Museum, Aylesbury .	220	—
Burnley Literary and Scientific Club. 1873.	Dr. Mackenzie, Burnley . .	209	—
Burton-on-Trent Natural History and Archæological Society. 1876.	Cocoa Café, Horninglow Street, Burton-on-Trent.	226	—
Cambrian Archæological Association. 1846.	Rev. R. T. Owen, Llangedwyn Vicarage, Oswestry.	308	—
Cambridge Antiquarian Society. 1840.	Rev. S. S. Lewis, Corpus Christi College, Cambridge.	300	—
Cambridge Philosophical Society. 1819.	New Museums, Cambridge .		21 0
Cardiff Naturalists' Society. 1867.	Dr. Vachell, 38 Charles Street, Cardiff.	413	—
Cheltenham Natural Science Society. 1877.	E. Wethered, 5 Berkeley Place, Cheltenham.	93	—
Chester Society of Natural Science. 1871.	G. R. Griffith, Grosvenor Street, Chester.	558	—
Chesterfield and Derbyshire Institute of Mining, Civil and Mechanical Engineers. 1871.	Stephenson Memorial Hall, Chesterfield.	288	21 0
Chichester and West Sussex Natural History and Microscopical Society. 1873.	Dr. Paxton, West Street, Chichester.	148	—
Cleveland Institution of Engineers. 1864.	A. Macpherson, 4 Milton Street, Middlesbrough-on-Tees.	360	—
Cleveland Naturalists' Field Club and University Extension Society. 1881.	J. J. Burton, Royal Exchange, Middlesbrough-on-Tees.	100	2 6
Clifton College Scientific Society. 1869.	Clifton College, Bristol . .	100	—
Cornwall, Mining Institute of. 1876.	W. Rich, Jun., Redruth, Cornwall.	138	—

Societies'—*continued.*

Annual Subscription.	Title and Size of Publications	Frequency of Issue	Remarks
s. *d.* 10 0	*Annual Report and Abstract of Proceedings*, 8vo. *Annual Report*, 8vo. . . .	Last vol. 1878 . . Since 1878 only.	Library.
10 6	*Transactions*, 8vo. . . .	2 pts. annually.	
10 0	*Proceedings*, 8vo. . . .	1 pt. annually. 3 pts. = 1 vol.	
6 0	*Records of Buckinghamshire*, 8vo.	1 no. annually. 8 nos. = 1 vol. 4 vols. and 4 nos. issued.	Museum.
10 0	*The Burnley Grammar School Library.*	1881. Will publish Proceedings this year.	
5 0 1 0	*Annual Report*, 8vo. . . *Catalogue of Ancient Remains found at Stapenhill, Derbyshire*, 8vo.	. . . . . 1882.	M.U. Museum and Library.
21 0	*Archæologia Cambrensis* . .	Quarterly. 36 annual and a few extra vols. published.	16 Local Secretaries, one for each county of the Principality and the Marches.
21 0	*Report and Communications*, 8vo., and occasional independent publications, 8vo.	At intervals of a few months.	
21 0	*Proceedings*, 8vo. . . . *Transactions*, 4to.	. . . . .	Library. Incorporated 1832.
10 0	*Report and Transactions*, 8vo. .	Annually . . .	Museum and Library.
10 0	*Reports of Science Papers*, 8vo. reprinted from '*Cheltenham Examiner*.'	Bound up into a vol. annually.	M.U.
5 0	*Proceedings*, 8vo. . . . *Annual Report*, 8vo.	Irregularly. No. 1, 1874. No. 2, 1878.	Museum and Library.
31 6	*Transactions*, 8vo. . . .	A vol. annually in about 6 parts.	Museum and Library.
5 0 2 6	*Transactions*, 8vo. . . .	Annually. No. 1. 24 pp. 1882. No. 2. 62 pp. 1883.	
21 0	*Proceedings*, 8vo. . . .	6 nos. in 1882.	
2 6	*Middlesbro' and the District*, 8vo.		
varies	*Transactions*, 8vo. . . .	7 pts. issued to 1880 .	Museum and Library.
10 6	*Proceedings*, 8vo. . . .	Annually.	

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Cornwall, Royal Geological Society of. 1814.	G. B. Millett, Penzance . .	137	—
Cornwall, Royal Institution of. 1818.	Truro	250	—
Cornwall, Royal, Polytechnic Society. 1833.	Polytechnic Hall, Falmouth .	300 (about)	—
Cornwall and Devon, Miners' Association of. 1859.	W. Rich, Jun., Redruth, Cornwall.	285	—
Cotteswold Naturalists' Field Club. 1846.	Dr. Paine, Stroud, Gloucestershire.	94	20 0
Croydon Microscopical and Natural History Club. 1870.	C. P. Turner, The Chestnuts, North End, Croydon, Surrey.	268	—
Cumberland Association for the Advancement of Literature and Science. 1876.	R. Crowder, Eden Mount, Stanwix, Carlisle.	[23	—
Cumberland and Westmorland Antiquarian and Archæological Society. 1866.	T. Wilson, Highgate, Kendal .	370	—
Derbyshire Archæological and Natural History Society. 1878.	A. Cox, Mill Hill, Derby. . .	300 (about)	5 0
Devonshire Association for the Advancement of Science, Literature, and Art. 1862.	Rev. W. Harpley, Clayhanger Rectory, near Tiverton, Devon.	503	—
Dorset Natural History and Antiquarian Field Club. 1873.	Prof. Buckman, Bradford Abbas, Sherborne, Dorset.	200	—
Dudley and Midland Geological and Scientific Society and Field Club. 1862.	Mechanics' Institute, Dudley .	106	—
Dulwich College Science Society. 1878.	Dulwich College, London, S.E. .	84	1 0
Dumfriesshire and Galloway Scientific, Natural History, and Antiquarian Society. 1876.	J. Rutherford, Jardington, Dumfries.	175	2 6
Dundee Naturalists' Society. 1874.	F. W. Young, High School of Dundee, Dundee.	473	—
Ealing Microscopical and Natural History Society. 1877.	A. Ramsay, 4 Cowper Road, Acton, London, W.	101	—
Eastbourne Natural History Society. 1868.	F. G. Cooke, Trinity Chambers, Eastbourne.	125	2 6
East Kent Natural History Society. 1858.	G. H. Nelson, Whitefriars, Canterbury.	74	—
Edinburgh, Botanical Society of. 1836.	5 St. Andrew Square, Edinburgh.	415	—

Societies'—*continued.*

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. d. 21 0	*Transactions*, 8vo. . . .	Annually . . .	Museum and Library.
21 0	*Journal*, 8vo. . . . . *Cornish Fauna*, and miscellaneous publications.	About 2 pts. annually.	
10 0 5 0	*Annual Report*, 8vo. . . .	. . . . .	Annual Exhibition. Library.
5 0 &c.	*Reports and Proceedings*, 8vo. .	Annually . . .	Work mainly educational. Library.
15 0	*Proceedings*, 8vo.		
10 0	*Proceedings and Transactions*, 8vo.	10 nos. since 1870.	
5 0]	*Transactions*, 8vo. . . .	1 pt. annually. 7 pts. (vols.) published.	Comprises 11 Societies with 1,460 members. *See Appendix.*
10 6	*Transactions*, 8vo., about 250 pp.	Annually, in May.	
10 6	*Journal*, 8vo.	1 vol. annually.	
10 6	*Report and Transactions*, 8vo. .	1 vol. annually . .	Holds an annual meeting in a Devonshire town.
10 0	*Proceedings*, 8vo. . . . *The Spiders of Dorset*, 8vo. .	Vols. 1–4 published. 2 vols published.	
10 6	*Proceedings*, 8vo.	None since 1880. A pt. to be issued in 1883.	M.U. Museum.
2 6 4 6	*Annual Report*, 8vo.. . .	. . . .	Museum and Library.
2 6	*Transactions and Journal of the Proceedings*, 8vo. 80–90 pp.	Biennially . . .	Similar Society existed 1862 to 1875.
5 0 &c.	*Annual Report*, 8vo. . . Separate papers, 8vo. . .	. . . . . Occasionally.	Museum and Library.
10 0	*Annual Report*, 8vo. Separate papers, 8vo. . .	 Irregularly.	
7 6	*Transactions*, 8vo. . . .	Annually . .	Museum and Library.
10 0	*Report*, 8vo.	Annually.	
15 0	*Transactions and Proceedings*, 8vo. *Reports*	14 vols. published. 1 vol. published.	Library, Herbarium, and Museum.

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Edinburgh Geological Society. 1834.	W. I. Macadam, Surgeons' Hall, Edinburgh	330	10 6
Edinburgh Naturalists' Field Club. 1869.	A. Moffat, 320 Leith Walk, Edinburgh.	165	—
Erith and Belvedere Natural History and Scientific Society. 1878.	C. H. Goodman, Belvedere, Lesness Heath, Kent.	150	—
Essex Archæological Society. 1852.	Museum, Colchester Castle, Colchester.	230 (about)	—
Essex Field Club. (Epping Forest and County of Essex Naturalists' Field Club.) 1880.	W. Cole, Buckhurst Hill, Essex.	400	—
Folkestone Natural History Society. 1868.	H. Ullyett, Lyell House, Folkestone.	90	—
Glasgow Archæological Society. 1856.	W. G. Black, 88 West Regent Street, Glasgow.	209	—
Glasgow, Geological Society of. 1858.	207 Bath Street, Glasgow . .	230	—
Glasgow, Natural History Society of. 1851.	207 Bath Street, Glasgow . .	300	10 0
Glasgow, Philosophical Society of. 1803.	207 Bath Street, Glasgow . .	697	21 0
Goole Scientific Society. 1875 . .	J. Harrison, Tillage Works, Goole.	78	—
Hackney Microscopical and Natural History Society. 1877.	C. Willmott, Morley Hall, Triangle, Hackney, London, E.	116	—
Halifax Literary and Philosophical Society. 1830.	S. T. Rigge, Halifax . .	403	—
Hastings and St. Leonards Philosophical Society. 1858.	A. L. Ward, 4 St. Paul's Place, St. Leonards-on-Sea.	66	—
Hawick Archæological Society. 1856.	J. Cairns, Gladstone Street, Hawick.	145	—
Hertfordshire Natural History Society and Field Club. 1875.	Public Library, Watford, Herts.	288	10 0
High Wycombe Natural History Society. 1865.	T. Marshall, High Wycombe .	20 (about)	—
Holmesdale Natural History Club. 1857.	A. J. Crosfield, Carr End, Redhill, Surrey.	80	—
Huddersfield Naturalists' Society. 1847.	S. L. Mosley, Beaumont Park, Huddersfield. . . .	89	2 6 1 0

Societies'—*continued.*

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. d.			
12 6	*Transactions*, 8vo. . . .	From 1868, 4 vols. published.	Library.
5 0	*Transactions*, 8vo. . . .	Annually. Pt. 2, vol. i., 1883.	
5 0	*Annual Report*, 8vo.		
10 6	*Transactions*, 8vo. . . .	1 pt. annually. 4 pts. =1 vol.	Museum and Library.
	Catalogue of the Antiquities in the Colchester Museum, 8vo.	2nd ed., 1870.	
10 6	*Transactions*, 8vo. . . .	About 2 pts. annually. 7 pts. in 3 vols., 820 pp. published.	Museum and Library.
5 0	*Proceedings*, 4to. . . .	Occasionally . .	Museum and Library.
10 6	*Transactions*, 8vo. . . .	1 pt. annually . .	Library.
10 0	*Transactions*, 8vo. . . .	6 vols. in 15 pts. published.	Museum and Library.
5 0	*Proceedings*, 8vo. . . .	5 vols. in 11 pts. published.	Library.
21 0 5 0	*Proceedings*, 8vo. . . .	1 vol. annually . .	Library.
5 0 2 6	*Annual Report of the Committee*, 8vo.	. . . . . .	Y.N.U. Museum and Library.
	Separate papers, 8vo. . .	Occasionally.	
10 0	*Annual Report*, 8vo. . .	. . . .	Museum and Library.
25 0	*Report of the Council and Proceedings*, 8vo.	Annually . . .	Museum and Library.
10 6	*Transactions*, 8vo. . . .	1864 only.	
	Natural History of Hastings and St. Leonards.	1878.	
2 6	Report of Papers, no title, 4to.	For 1881–2, 48 pp. bound up in 1 vol.	Museum.
10 0	*Transactions*, 8vo. . . .	About 4 pts. annually, of 48 pp. each.	Founded as Watford Nat. Hist. Soc. Library and Herbarium.
2 6	*Quarterly Magazine*, 8vo. .	Discontinued. 2 vols. to June, 1870.	
	Annual Address of President separately.		
10 0	*Proceedings*, 8vo. . . .	Irregularly . . .	Museum and Library.
4 0 2 6	Catalogues of Fauna and Flora of District, 8vo.	1 pt. annually . .	Y.N.U.

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Hull Literary and Philosophical Society. 1822.	Royal Institution, Hull . .	584	—
Inverness Scientific Society and Field Club. 1875.	T. D. Wallace, High School, Inverness.	161	5 0
Ireland, Royal Geological Society of. 1831.	39 Trinity College, Dublin .	155	21 0
Ireland, Royal Historical and Archæological Association of. 1849.	Rev. J. Graves, Inisnag Glebe, Stoneyford, Co. Kilkenny.	478	40 0
Ireland, Statistical and Social Inquiry Society of. 1846.	35 Molesworth Street, Dublin .	250 (about)	—
Keighley Scientific and Literary Society. 1881.	A. Keighley, Flosh House, Keighley.	70	—
Kent Archæological Society. 1857.	The Museum, Maidstone . .	900	10 0
Kirkcaldy Naturalists' Society. 1882.	W. D. Sang, 12 Townsend Crescent, Kirkcaldy	132	—
Lambeth Field Club and Scientific Society. 1872.	Old Vestry Hall, 135 Lambeth Road, London, S.E.	39	1 0
Lancashire and Cheshire Antiquarian Society. 1883.	G. C. Yates, Swinton, Manchester.	220	10 6
Lancashire and Cheshire Entomological Society. 1877.	J. W. Ellis, 101 Everton Road, Liverpool.	67	—
Lancashire and Cheshire, Historic Society of. 1831.	Royal Institution, Liverpool .	230	—
Largo Field Naturalists' Society. 1863.	C. Howie, Largo, Fifeshire .	51	7 6
Leeds Naturalists' Club and Scientific Association. 1870.	H. Pollard, 19 Britannia Terrace, New Wortley, Leeds.	230	—
Leeds Philosophical and Literary Society. 1820.	Museum, Leeds	629	—
Leicester Literary and Philosophical Society. 1835.	Town Museum, Leicester . .	317	—
Lewes and East Sussex Natural History Society. 1864.	J. H. A. Jenner, 4 East Street, Lewes.		5 0
Lewisham and Blackheath Scientific Association. 1879.	H. W. Jackson, 159 High Street, Lewisham, London, S.E.	130	—

Societies'—*continued.*

Annual Subscription		Title and Size of Publications	Frequency of Issue	Remarks
s.	*d.*			
21	0	*Annual Report of the Council and Transactions*, 8vo.	. . . . .	Museum and Library.
5	0	*Transactions*, 8vo. . . .	. . . . .	*Transactions* from 1875 in course of republication.
21	0	*Journal*, 8vo.	Annually.	
10	0			
20	0	*Journal*, 8vo.	Quarterly, in 4 Series, 17 vols. published.	Founded as the Kilkenny Arch. Soc.
		Annual Volume, 8vo. . .	For 1868–9 = 1 vol.	
		ditto 4to. . .	For 1870–77 in 8 pts. = 2 vols.	
21	0	*Journal*, 8vo.	Half-yearly.	
4	0	*Journal*, 4to. 16 pp. . . .	Quarterly . . .	Y.N.U.
2	6			
10	0	*Archæologia Cantiana*, 8vo. .	Annually. 15 vols. published.	Museum.
5	0	Separate papers, 8vo. . .	Occasionally.	
6	0	*Report*, 8vo.	Annually . . .	Library.
10	6	*Transactions*, 8vo. . . .	Annually.	
5	0	*Annual Report*, 8vo., and Papers reprinted from the 'Naturalist'	. . . . .	Library.
10	6	*Proceedings*, 8vo.		
21	0			
2	6	*Report of Annual Meeting*, 8vo.	1881 and 1882 only .	Museum.
2	6	*Annual Report*	. . . . .	Y.N.U.
to		*The Natural History of Leeds, Wharfedale and Nidderdale*, 8vo.	In preparation.	
21	0			
21	0	*Transactions*, 8vo. . . .	1837	Museum and Library.
7	6	*Annual Report*, 8vo.		
		Catalogue of the Library . .	1883.	
21	0	*Transactions*, 8vo. . . .	9 pts. issued, containing proceedings to June, 1879. For 1881–3, published with Report.	M.U. Library.
		Report of the Council, 8vo. .	Annually.	
5	0	*Annual Report*, 8vo. . .	None since 1878 . .	Library.
10	6	*Annual Report*, 8vo.		
		Report of the Committee for the exploration of the Subsidences on Blackheath, 8vo.	1881.	

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Liverpool Astronomical Society. 1882.	W. H. Davies, 55 Great Newton Street, Liverpool.	86	—
Liverpool Engineering Society. 1875.	Royal Institution, Liverpool .	112	—
Liverpool Geological Association. 1880.	Free Library, William Brown Street, Liverpool.	131	—
Liverpool Geological Society. 1859.	G. H. Morton, 122 London Road, Liverpool.	67	—
Liverpool, Literary and Philosophical Society of. 1812.	Royal Institution, Liverpool .	333	10 6
Liverpool, Microscopical Society of. 1868.	Royal Institution, Liverpool .	180	—
Liverpool Naturalists' Field Club. 1860.	Rev. W. Banister, St. James's Mount, Liverpool.	420	—
Liverpool Polytechnic Society. 1838.	Royal Institution, Liverpool .	221	—
London and Middlesex Archæological Society. 1855.	4 St. Martin's Place, Trafalgar Square, London, S.W.		10 0
Macclesfield Scientific Students' Association. 1880.	Useful Knowledge Society, Macclesfield.	18	—
Malvern Naturalists' Field Club. 1852.	H. Wilson, Eastnor, Malvern Link.	80	10 0
Manchester Field Naturalists' and Archæologists' Society. 1860.	A. Griffiths, 16 Kennedy Street, Albert Square, Manchester.	220	—
Manchester Geological Society. 1838.	36 George Street, Manchester .	222	—
Manchester Literary and Philosophical Society. 1781.	36 George Street, Manchester .	181	42 0
Manchester—Lower Mosley Street Schools Natural History Society. 1861.	H. Hyde, 37 Cottenham Street, Upper Brook Street, Manchester.	38	1 0
Manchester Scientific Students' Association. 1861.	97 Bridge Street, City, Manchester.	370	2 6
Manchester Statistical Society. 1833.	Memorial Hall, 44 Brown Street, Manchester.	205	10 6
Man, Isle of, Natural History and Antiquarian Society. 1879.	P. M. C. Kermode, Seabridge Cottage, Ramsey, Isle of Man.	64	—
Marlborough College Natural History Society. 1864.	The College, Marlborough, Wilts.	76	2 6

Societies'—*continued.*

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. d.			
5 0	*Transactions*, 8vo. . . . *Abstracts of Proceedings*, 8vo. .	Occasionally. Vol. i. 1882–3.	
21 0 10 6	*Transactions*, 8vo. . . *Annual Report*, 8vo.	Annually from 1881 .	Library.
5 0	*Transactions*, 8vo. . . .	1 vol. annually . .	Library.
21 0	*Proceedings*, 8vo. . . .	Annually . . .	Library.
21 0	*Proceedings*, 8vo. . .	1 vol. annually; 36 vols. published since 1845.	Library.
10 6	*Annual Report*, 8vo. . .	. . . . .	Library and Cabinet of Slides.
5 0	*Proceedings*, 8vo. . .	Annually.	
11 0	*Journal*	. . . . .	Library.
21 0	*Transactions*, 8vo. . . . *Proceedings of Evening Meetings.* Separate papers.	5 vols. published.	
10 0	Separate papers, 8vo. . .	Occasionally.	
5 0	*Transactions*	Occasionally.	
10 6	*Report and Proceedings*, 8vo. .	Annually.	
20 0	*Transactions*, 8vo. . . .	9 pts. annually = about 1 vol. in 2 years.	Library.
42 0	*Proceedings*, 8vo. . . . *Memoirs*, 8vo.	1 vol. annually. Occasionally.	
2 0	*Report*, 8vo.	Annually.	
10 0	*Report and Proceedings*, 8vo. .	Annually.	
10 6	*Transactions*, 8vo. . . .	Annually . . .	Library.
5 0 2 6	*Annual Reports*, 8vo. Reports of Meetings and Excursions, reprinted from '*Mona's Herald.*'	Occasionally.	
3 0	*Report*, 8vo.	1 vol. annually . .	Museum.

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Midland Institute of Mining, Civil and Mechanical Engineers. 1857.	Eldon Street, Barnsley, Yorkshire.	166	—
Midland Union of Natural History Societies. 1877.	W. J. Harrison, 365 Lodge Road, Birmingham.		
Montrose Natural History and Antiquarian Society. 1836.	Museum, Montrose . . .	164	—
Newbury District Field Club. 1870.	W. Money, Herborough House, Newbury.	134	5 0
Newcastle-upon-Tyne Literary and Philosophical Society. 1793.	Newcastle-upon-Tyne. . .	1200	—
Newcastle-upon-Tyne, Society of Antiquaries of. 1813.	The Castle, Newcastle-upon-Tyne.	200 (about)	—
Norfolk and Norwich Archæological Society. 1846.	R. Fitch, Norwich . . .	300 (about)	—
Norfolk and Norwich Naturalists' Society. 1869.	W. H. Bidwell, Norwich . .	237	—
North of England Institute of Mining and Mechanical Engineers. 1852.	Newcastle-upon-Tyne . .	852	—
North Oxfordshire, Archæological Society of. 1853.	Rev. W. D. Macray, Ducklington Rectory, Witney.	60	—
North Staffordshire Institute of Mining and Mechanical Engineers. 1872.	J. R. Haines, Adderley Green Collieries, Stoke-on-Trent.	262	—
North Staffordshire Naturalists' Field Club and Archæological Society. 1865.	Rev. T. W. Daltry, Madeley Vicarage, Newcastle, Staffordshire.	374	5 0
Northamptonshire Natural History Society and Field Club. 1876.	S. J. Newman, 32 Abington Street, Northampton.	240	—
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of. 1829.	Museum of the Natural History Society, Newcastle-upon-Tyne.	150	—
Norwich Geological Society. 1864.	J. Orfeur, The Close, Norwich. .	72	—
Norwich Science Gossip Club. 1870.	F. H. Ellingham, Thorpe St. Andrew, Norwich.	61	1 0
Nottingham Naturalists' Society. 1852.	B. S. Dodd, 33 Beech Avenue, New Basford, Nottingham.	139	—

Societies'—*continued.*

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. d. 21 0	*Transactions*, 8vo. . . .	About 8 pts. annually.	
	Midland Naturalist, 8vo. . .	Monthly, forming one vol. annually.	Includes 21 Societies, with 2,683 members. *See Appendix.*
5 0	*Report of the Directors*, 8vo. *List of British Birds in the Society's Collections*, 8vo.	Annually . . . 1881.	Museum.
5 0	*Transactions*, 8vo. . . .	Vol. i. 1870; vol. ii. 1872–5.	
21 0	*Proceedings*	. . . .	Library.
21 0	*Proceedings*, 8vo. . . . *Archæologia Æliana*, 8vo., and other publications.	Monthly. Irregularly.	
7 6	*Original Papers*, 8vo. . . .	9 vols. since 1846.	
5 0	*Transactions*, 8vo. . . .	1 pt. annually . .	Library.
21 0 42 0 63 0	*Transactions*, 8vo. . . .	1 vol. annually. 32 vols. published.	Incorporated in 1876.
5 0	*Transactions*, 8vo. . . .	Irregularly.	
21 0	*Transactions*, 8vo. . . .	6 vols., & pt. 1, vol. 7, published.	Library.
5 0	*Annual Report*, 8vo. . .	17 vols. published.	Library.
10 0	*Journal*, 8vo.	Quarterly. Vol. i. 1880–1, ii. 1882–3.	M.U. Library.
21 0	*Natural History Transactions of Northumberland, Durham, and Newcastle-upon-Tyne*, 8vo.	7 vols issued. (Include proceedings of the Tyneside Naturalists' Field Club.)	Museum.
5 0	*Proceedings*, 8vo. . . .	1 no. annually.	
4 0	*Report of Proceedings at the Annual Meeting*, 8vo.		
5 0 2 6	*Annual Report (with Transactions)*, 8vo.	. . . .	M.U. Library.

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Oswestry and Welshpool Naturalists' Field Club and Archæological Society. 1857.	Rev. O. M. Feilden, Frankton Rectory, Oswestry.	40	5 0
Oxford—Ashmolean Society. 1828.	University Museum, Oxford.	266	—
Penzance Natural History and Antiquarian Society. 1839.	G. B. Millett, Chapel Street, Penzance.	82	—
Perthshire Society of Natural Science. 1867.	Perthshire Natural History Museum, Tay Street, Perth.	295	2 6
Plymouth Institution and Devon and Cornwall Natural History Society. 1812.	Athenæum, Plymouth . .	262	—
Powys-land Club. 1867 . . .	Powys-land Museum and Library, Welshpool.	180	—
Rochester Naturalists' Club. 1878.	J. Hepworth, 2 Union Street, Rochester.	74	2 6
Rugby School Natural History Society. 1866.	Rev. F. D. Morice, Rugby .	167	—
Scarborough Philosophical and Archæological Society. 1830.	J. H. Phillips, Museum, Scarborough.	70 (about)	—
Severn Valley Naturalists' Field Club. 1863.	R. W. Ralph, Honnington Grange, Newport, Salop.	65	5 0
Sheffield Literary and Philosophical Society. 1823.	School of Art, Sheffield . .	385	—
Sheffield Naturalists' Club. 1872 .	J. C. Burrell, 5 King Street, Sheffield.	217	—
Shropshire Archæological and Natural History Society. 1835.	F. Goyne, Dogpole, Shrewsbury.	230	—
Somersetshire Archæological and Natural History Society. 1849.	Taunton Castle, Taunton . .	500 (about)	10 6
Southampton Literary and Philosophical Society. 1863.	Morris Miles, Hill, near Southampton.	75	—
South London Entomological Society. 1872.	94 New Kent Road, London, S.E.	53	1 0

Societies'—*continued.*

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. *d.* 5 0	*Report of Meetings*, 8vo. . .	No publications since 1865. A no. about to be issued.	M.U.
21 0	*Transactions*, 8vo. . . . *Journal of the Proceedings*, 8vo. *Catalogue of Library*, 8vo. . Separate papers, 8vo. . .	. . . . . Once or twice a year. 1878. Occasionally.	Museum and Library.
10 6	*Report and Transactions*, 8vo.	1 pt. annually. 4 pts. = 1 vol.	Museum and Herbarium.
5 6	*Proceedings*, 4to. . . .	1 pt. annually . .	Museum and Library.
20 0	*Annual Report and Transactions*, 8vo.	7 vols. and 2 pts. vol. viii. issued.	Museum and Library.
21 0	*Montgomeryshire Collections*, 8vo.	1 vol. annually. 16 vols. published.	Museum and Library.
3 6	*Rochester Naturalist*, 8vo. .	Quarterly, commencing July 1883.	
7 6	*Report*, 8vo.	1 vol. annually . .	Temple Observatory.
20 0	*Report*, 8vo.	Annually . . .	Museum and Library.
5 0	*Report of the Field Meetings*, 8vo. Separate papers, 8vo. . .	Every two or three years. Occasionally.	M.U.
10 6 21 0 42 0	*Annual Report*, 8vo. . .	. . . . .	Library.
10 6 5 0	*Annual Report and Record of Transactions*, 8vo.	. . . . .	Y.N.U.
21 0	*Transactions*, 8vo. . . .	3 pts. forming 1 vol. annually. 18 pts. issued since 1878.	Museum and Library (College Hill, Shrewsbury).
10 6	*Proceedings*, 8vo. . . .	1 vol. annually. 28 vols. issued.	Museum and Library.
10 0	. . . .	. . . . .	Not published last few years, but will be again.
6 0	*Report*, 8vo.	Annually . . .	Library and Cabinet.

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
South London Microscopical and Natural History Club. 1871.	Brixton Hall, Acre Lane, Brixton, London, S.W.	152	—
South Staffordshire and East Worcestershire Institute of Mining Engineers. 1867.	Mining Museum, Dudley . .	205	21 0
South Wales Institute of Engineers. 1847.	Hort. Huxham, Swansea . .	230	21 0
Stafford—William Salt Archæological Society. 1879.	William Salt Library, Stafford .	220	—
Stirling Natural History and Archæological Society. 1878.	D. Chrystal, 11 King Street, Stirling.	58	—
Stroud Natural History and Philosophical Society. 1876.	E. N. Witchell, The Acre, Stroud, Gloucestershire.	60	—
Suffolk Institute of Archæology and Natural History. 1848.	F. M. Smith, 16 Westgate, Bury St. Edmund's.	110	10 0
Surrey Archæological Society. 1854.	8 Danes Inn, Strand, London, W.C.	423	10 0
Sussex Archæological Society. 1846 .	The Castle, Lewes . . .	612	10 0
Swansea Scientific Society. 1876.	Royal Institution of South Wales, Swansea.	53	—
Tamworth Natural History, Geological, and Antiquarian Society. 1870.	W. G. Davy, Elford, Tamworth .	141	—
Teign Naturalists' Field Club. 1858.	G. W. Ormerod, Woodway, Teignmouth, Devon.	120	—
Tyneside Naturalists' Field Club. 1846.	Museum of the Natural History Society, Newcastle-upon-Tyne.	600	5 0
Wakefield Naturalists' and Philosophical Society. 1871.	E. B. Wrigglesworth, Thornes, Wakefield.	80	2 6
Warrington Literary and Philosophical Society. 1869.	J. R. Young, Sankey Street, Warrington.	160 (about)	—
Warwick and Warwickshire Natural History and Archæological Society. 1836.	Museum, Warwick . . .	73	—
Warwickshire Naturalists' and Archæologists' Field Club. 1854.	Rev. P. B. Brodie, Rowington Vicarage, Warwick.	84	2 6

Societies'—*continued.*

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. d.			
10 0	*Annual Report*, 8vo. . . . Map of the district . . .	. . . . . 1878.	Library.
21 0	*Transactions*, 8vo. . . .	. . . . .	Museum.
42 0	*Proceedings*, 8vo. . . .	12 vols. issued . .	Incorporated 1881.
21 0	*Collections for a History of Staffordshire*, 8vo.	1 vol. annually.	
5 0 1 0	*Transactions*, 8vo. . . .	3 vols. published .	Museum and Library.
10 0	*Transactions*, 8vo. . . .	2 pts. issued . .	M.U.
10 0	*Proceedings*, 8vo.		
10 0	*Surrey Archæological Collections*, 8vo.	1 pt. annually. 8 vols. published.	Museum (Croydon). Library (Danes Inn).
10 0	*Sussex Archæological Collections*, 8vo.	33 vols. published.	
5 0	*Annual Report*, 8vo.		
5 0	*Proceedings*	Only 1 vol. issued .	M.U.
2 6	*Report of the Proceedings*, 8vo.	Annually.	
5 0	*Transactions* . . . . *Proceedings*	1846 to 1863, vols. i.–vi. Since 1863 . . .	Jointly with Nat. Hist. Soc. Newcastle-on-Tyne.
10 6 4 0	*Annual Report, with Extracts from the Transactions*, 8vo.	. . . . .	Y.N.U. Museum and Library.
5 0	*Proceedings*	Annually.	
21 0	*Annual Report*, 8vo. . .	. . . . .	Museum and Library.
5 0	*Proceedings*, 8vo. . . .	Annually.	

List of 'Local Scientific

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee
			s. d.
Waterford Literary and Scientific Association. 1876.	J. Dowling, Newtown Buildings, Waterford.	114	—
Wellington College Natural Science Society. 1868.	S. A. Saunder, Wellington College, Wokingham.	112	—
West Kent Natural History, Microscopical, and Photographic Society. 1859.	Post Office, Lee Bridge, Lewisham, London, S.E.	104	—
Whitby Literary and Philosophical Society. 1822.	Museum, Whitby . . .	61	21 0
Wiltshire Archæological and Natural History Society. 1853.	Museum, Devizes . . .	368	10 6
Winchester College Natural History Society. 1871.	R. H. Fuller, Winchester College, Winchester.	25	0 6
Woolhope Naturalists' Field Club. 1851.	T. Lane, Broomy Hill, Hereford.	187	10 0
Worcestershire Naturalists' Field Club. 1853.	J. S. Haywood, 26 Broad Street, Worcester.	125	10 0
York School Natural History, Literary, and Polytechnic Society. 1833.	20 Bootham, York . . .	150	—
Yorkshire Archæological and Topographical Association. 1863.	G. W. Tomlinson, The Elms, Huddersfield.	533	—
Yorkshire Geological and Polytechnic Society. 1837.	James W. Davis, Chevinedge, Halifax.	220	—
Yorkshire Naturalists' Club. 1849.	C. Wakefield, Heslington House, York.	75	—
Yorkshire Naturalists' Union. 1861.	W. D. Roebuck, Sunny Bank, Leeds.	[300	—
Yorkshire Philosophical Society. 1823.	Museum, York	446	60 0

Societies'—*continued.*

Annual Subscription	Title and Size of Publications	Frequency of Issue	Remarks
s. d. 10 6	*Proceedings*, 8vo. . . .	1 vol. issued, for 1880–1.	Museum.
4 6 3 0	*Annual Report*, 8vo.		
10 6	*President's Address, Papers and Reports*, 8vo.	1 vol. annually . .	Library.
10 6	*Report*, 8vo.	Annually . . .	Museum.
10 6	*Wiltshire Archæological and Natural History Magazine*, 8vo.	Half-yearly, 21 vols. issued.	Museum, Herbarium and Library.
6 0	*Report*, 8vo.	6 nos. published.	
10 0	*Transactions*, 8vo. *Herefordshire Pomona*, fol.		
5 0	*Flora of Worcestershire*, 8vo. *Reports of Excursions.*	1 vol.	
2 0	*Annual Report*, 8vo. . . Papers in '*Natural History Journal*,' 8vo.	. . . . . . Monthly, except January, July, and August.	Observatory.
10 6	*Yorkshire Archæological and Topographical Journal*, 8vo., and miscellaneous publications.	2 pts. annually. Vols. i.–vii. and pt. 1, vol. viii. issued.	Library (Huddersfield).
13 0	*Proceedings*, 8vo. . . .	1 no. annually.	
5 0	*Proceedings*	Annually to 1874, irregularly since.	
5 0 &c.	*Transactions*, 8vo. . . . '*The Naturalist*,' 8vo. . .	1 pt. annually. Since 1876, 6 pts. Monthly, forming 1 vol. annually.	Re-organised 1876. 2,489 members of the 38 affiliated Societies. *See Appendix.*
40 0	*Annual Report*, 8vo.. . . . *Proceedings*, 8vo. . . .	. . . . . . Occasionally.	Museum, Library, &c.

APPENDIX.

THE CUMBERLAND ASSOCIATION FOR THE ADVANCEMENT OF LITERATURE AND SCIENCE, CONSISTS OF THE FOLLOWING SOCIETIES.

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee	Annual Subscription
				s. d.
Ambleside and District Literary and Scientific Society. 1878.	C. W. Smith, Fisherbeck, Ambleside.	136	—	5 0
Brampton Literary and Scientific Society, and Field Naturalists' Club. 1881.	C. J. Rigg, Brampton, Carlisle.	65	—	2 6 1 0
Carlisle Scientific Society, and Field Naturalists' Club. 1877.	J. Sinclair, 6 Hawick Street, Carlisle.	206	—	5 0 2 6
Keswick Literary and Scientific Society. 1868.	T. E. Highton, Brigham, Keswick.	145	—	3 6 2 6
Longtown Literary and Scientific Society. 1874.	J. Wilson, Eskbank, Longtown, Cumberland.	58	—	2 6
Maryport Literary and Scientific Society. 1876.	J. Hewetson, Maryport .	124	—	5 0 2 6
Penrith and District Literary and Scientific Society. 1881.	Rev. J. S. Ostle, Beaconside, Penrith.	120 (about)	—	5 0 2 6
Silloth and Holme Cultram Literary and Scientific Society. 1879.	H. L. Barker, Esk Street, Silloth, Cumberland.	70	—	2 6
Whitehaven Scientific Association. 1866.	W. H. Kitchin, Howgill Street, Whitehaven.	336	—	5 0 10 0
Windermere Literary and Scientific Society. 1882.	W. C. Macdougall, Windermere.	100	—	5 0 2 6
Workington Scientific and Literary Association. 1874.	W. Wilson, Brow Top, Workington.	100		

THE FOLLOWING SOCIETIES FORM THE MIDLAND UNION OF NATURAL HISTORY SOCIETIES.

* Inserted with particulars in General List.

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee	Annual Subscription
			s. d.	s. d.
*Bedfordshire Natural History Society and Field Club.				
Birmingham High School Natural History Society. 1869.	King Edward's High School, New Street, Birmingham.	56	—	2 0
Birmingham Microscopists' and Naturalists' Union. 1880.	P. T. Deakin, 46 Princess Road, Edgbaston, Birmingham.	50 (about)	—	5 0
Birmingham and Midland Institute Scientific Society. 1872.	Midland Institute, Birmingham.	224	—	3 0
*Birmingham Natural History and Microscopical Society.				
*Birmingham Philosophical Society.				
*Burton-on-Trent Natural History and Archæological Society.				
Caradoc Field Club. 1863.	R. H. Law, Copthorne House, Shrewsbury.	65	—	5 0
*Cheltenham Natural Science Society.				
*Dudley and Midland Geological and Scientific Society and Field Club.				
Evesham Field Naturalists' Club. 1873.	T. E. Dolg, 57 Bridge Street, Evesham.	35	—	2 6
*Leicester Literary and Philosophical Society.				
*Northamptonshire Natural History Society and Field Club.				
*Nottingham Naturalists' Society.				
Nottingham Working Men's Naturalists' Society. 1875.	'Sir Francis Burdett' Inn, Mount Street, Nottingham.	32	1 9	4 4
*Oswestry and Welshpool Naturalists' Field Club and Archæological Society.				
Oxfordshire Natural History Society. 1879.	G. C. Druce, 118 High Street, Oxford.	50 (about)	—	5 0
Peterborough Natural History Scientific and Archæological Society. 1872.	J. W. Bodger, 18 Cowgate, Peterborough.	118	—	5 0 10 6 21 0
*Severn Valley Naturalists' Field Club.				
*Stroud Natural History and Philosophical Society.				
*Tamworth Natural History, Geological, and Antiquarian Society.				

THE YORKSHIRE NATURALISTS' UNION INCLUDES THE FOLLOWING SOCIETIES.

* Inserted with particulars in General List.

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary	Number of Members	Entrance Fee	Annual Subscription
			s. d.	s. d.
*Barnsley Naturalists' Society.				
Beverley Field Naturalists' and Scientific Society. 1881.	J. D. Butterell, Willow Grove, Beverley.	80	—	5 0
Bradford Microscopical Society. 1882.	C. E. Waddington, 31 Darley Street, Bradford.	72	—	5 0 10 0
Bradford Naturalists' Society. 1875.	J. Eastwood, 22 White's Terrace, Bradford.	50	1 0	4 0
Bradford Scientific Association. 1873.	J. E. Wilson, 8 Summerseat Place, Bradford.	36	—	4 0
Clayton-West Naturalists' Society. 1862.	W. Waite, Clayton-West, Huddersfield.	24	1 0	4 0
Dewsbury Naturalists' Society. 1879.	J. Summersgill, Moorlands, Dewsbury.	56	—	2 6
Doncaster Microscopical and General Scientific Society. 1880.	M. H. Stiles, 2 Frenchgate, Doncaster.	80	—	5 0
Driffield Literary and Scientific Society. 1870.	C. Forbes Sharp, Driffield, Yorkshire.	10	—	2 6
Elland-cum-Greetland Naturalists' Society. 1867.	A. Fielding, Woodfield House, Greetland, Halifax.	45	1 0	3 0
*Goole Scientific Society.				
Halifax Scientific Society. 1874.	C. L. Baker, Halifax . .	162	—	1 0
Heckmondwike Naturalists' Society. 1861.	J. Norcliffe, Market Street, Heckmondwike, Normanton.	12	2 6	4 4
Holmfirth Naturalists' Society (Olive Branch Botanical Society). 1855.	J. Taylor, Hollowgate, Holmfirth, Huddersfield.	18	1 0	1 0
Honley Naturalists' Society. 1874.	A. Boothroyd, Brockholes, Huddersfield.	45	0 6	2 0
Huddersfield Literary and Scientific Society. 1857.	South Street, Huddersfield.	140	—	10 0
*Huddersfield Naturalists' Society.				
Hull Field Naturalists' Society. 1880.	W. Officer, 38 Louis Street, Hull.	34	—	4 0
Ilkley Scientific Club. 1882.	J. Brodie, Heath Royd, Ilkley.	60	—	2 6
*Keighley Scientific and Literary Society.				
Leeds Conchological Society (Conchological Society of Great Britain and Ireland). 1876.	T. W. Bell, 10 Reuben Place, Leeds.	28	—	5 0
Leeds Geological Association. 1874.	Yorkshire College, Cookridge Street, Leeds.	33	—	4 0

YORKSHIRE NATURALISTS' UNION—*continued.*

Full Title of Society and Date of Foundation	Head Quarters, or Name and Address of Secretary.	Number of Members	Entrance Fee	Annual Subscription
			s. d.	*s. d.*
*Leeds Naturalists' Club and Scientific Association.				
Liversedge Naturalists' Society. 1872.	J. Rothery, Millbridge, Liversedge, Normanton.	19	1 0	2 0
Malton Field Naturalists' and Scientific Society. 1880.	T. Lister, Vine Street, Norton, Malton.	80	—	5 0
Mirfield Naturalists' Society. 1874.	T. Cardwell, East Thorpe, Mirfield, Normanton.	16	1 0	3 0
Ovenden Naturalists' Society. 1870.	Hope Cottage, Shay Lane, Ovenden, Halifax.	30	1 0	3 0
Rastrick-cum-Brighouse Naturalists' Society. 1867.	J. Ellis, Rock Place, Manley Estate, Brighouse.	30	2 6	5 0
Ripon Naturalists' Club and Scientific Association. 1882.	Museum, Park Street, Ripon.	178	—	4 0 &c.
Ripponden Naturalists' Society. 1871.	W. C. Moores, Ripponden, Halifax.	15	1 0	4 0
Rotherham Naturalists' Society. 1880.	F. W. Dickinson, 26 Bridgegate, Rotherham.	63	—	10 6 5 0
Scarborough Scientific Society. 1879.	G. Massee, Oak House, Oak Road, Scarborough.	20	5 0	5 0
Selby Naturalists' Society. 1875.	W. N. Cheesman, The Crescent, Selby.	77	2 6	2 6
*Sheffield Naturalists' Club.				
Shipley Field Naturalists' Club. 1880.	W. Riley, Baildon Royd, Shipley.	18 (about)	—	2 0
*Wakefield Naturalists' and Philosophical Society.				
York and District Field Naturalists' Society. 1874.	W. Prest, 13 Holgate Road, York.	70 (about)	—	4 0
York—St. Thomas's Field Naturalists' Society. 1881.	S. Walker, 8 Neville Street, Haxby Road, York.	34	—	4 0

On some Results of Photographing the Solar Corona without an Eclipse. By WILLIAM HUGGINS, *D.C.L., LL.D., F.R.S.*

[PLATE XI.]

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

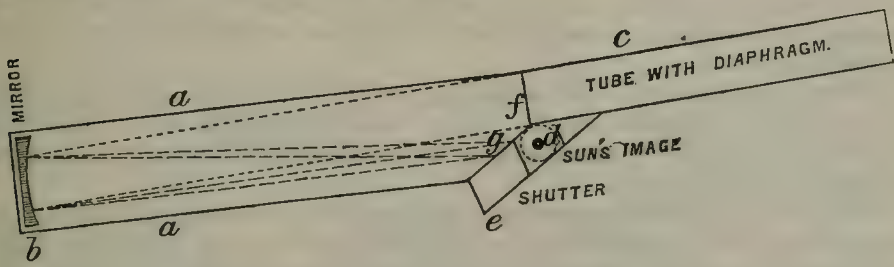
LAST December (1882) I had the honour of presenting to the Royal Society a note on 'A Method of Photographing the Solar Corona without an Eclipse.' In that paper I say:—'If by screens of coloured glass or other absorptive media the region of the spectrum between G and H could be isolated, then the coronal light which is here very strong would have to contend only with a similar range of refrangibility of the light scattered from the terrestrial atmosphere. It appeared to me by no means improbable that under these conditions the corona would be able so far to hold its own against the atmospheric glare, that the parts of the sky immediately about the sun where the corona was present would be in a sensible degree brighter than the adjoining parts where the atmospheric light alone was present. It was obvious, however, that in our climate and low down on the earth's surface, even with the aid of suitable screens, the addition of the coronal light behind would be able to increase but in a very small degree the illumination of the sky at those places where it was present. There was also a serious drawback from the circumstance that although this region of the spectrum falls just within the range of vision, the sensitiveness of the eye for very small differences of illumination in this region near its limit of power is much less than in more favourable parts of the spectrum; at least such is the case with my own eyes. There was also another consideration of importance; the corona is an object of very complex form, and full of details depending on small differences of illumination, so that even if it could be glimpsed by the eye, it could scarcely be expected that observations of a sufficiently precise character could be made to permit of the detection of the more ordinary changes which are doubtlessly taking place in it. These considerations induced me not to attempt eye-observations, but from the first to use photography, which possesses extreme sensitiveness in the discrimination of minute differences of illumination, and also the enormous advantage of furnishing a permanent record from an instantaneous exposure of the most complex forms.'

The photographs described in that paper were obtained with a reflecting telescope of the Newtonian form by Short, and the restriction of the light to the small range of refrangibility from about G to H was effected by the use of screens of coloured glass, or by a cell containing a solution of potassic permanganate. The photographs showed distinctly coronal appearances around the sun, and I was permitted by Captain Abney, F.R.S., who made a careful examination of the plates, to say that, in his opinion, the solar corona had been photographed on my plates with an uneclipsed sun.

I purpose in this paper to give an account of some further experiments founded on the same method made during the spring and summer of the present year.

I am indebted to Miss Lassell for the loan of a seven-foot Newtonian telescope made by the late Mr. Lassell. The speculum, which is seven

inches in diameter, possesses great perfection of figure, and still retains its original fine polish. I decided not to use more than $3\frac{1}{2}$ inches of the central portion of the speculum, partly for the reason that a larger amount of light would be difficult of management, and partly because this restriction of the aperture would enable me to adopt the arrangement which is shown in the diagram.



It will be seen at once from an inspection of the diagram that in this arrangement the disadvantage of a second reflection by the small mirror is avoided, as is also the mechanical inconvenience of tilting the speculum within in the tube as in the ordinary form of the Herschelian telescope. The speculum *b* remains in its place at the end of the tube *a*, *d*. The small plane speculum and the arm carrying it were removed. The open end of the tube is fitted with a mahogany cover. In this cover at one side is a circular hole *f*, $3\frac{1}{4}''$ diameter, for the light to enter; below is a similar hole over which is fitted a framework to receive the 'backs' containing the photographic plates, and also to receive a frame with fine ground-glass for putting the apparatus into position. Immediately below, towards the speculum, is fixed a shutter with an opening of adjustable width, which can be made to pass across more or less rapidly by the use of india-rubber bands of different degrees of strength. In front of the opening *f* is fixed a tube *c*, six feet long, fitted with diaphragms, to restrict as far as possible the light which enters the telescope to that which comes from the sun and the sky immediately around it. The telescope-tube *a*, *a*, is also fitted with diaphragms, which are not shown in the diagram, to keep from the plate all light, except that coming directly from the speculum. It is obvious that, when the sun's light entering the tube at *f* falls upon the central part of the speculum, the image of the sun will be formed in the middle of the second opening at *d*, about two inches from the position it would take if the tube were directed axially to the sun. The exquisite definition of the photographic images of the sun shows, as was to be expected, that this small deviation from the axial direction, two inches in seven feet, does not affect sensibly the performance of the mirror. The whole apparatus is firmly strapped on to the refractor of the equatorial, and carried with it by the clock motion.

The performance of the apparatus is very satisfactory. The photographs show the sun's image sharply defined; even small spots are seen. When the sky is free from clouds, but presents a whity appearance from the large amount of scattered light, the sun's image is well-defined upon a uniform background of illuminated sky, without any great increase of illumination immediately about it. It is only when the sky becomes clear and blue in colour that coronal appearances present themselves with more or less distinctness.

In my earlier work with this apparatus I used cells containing

potassic permanganate in solution, which were placed close to the sensitive surface, and between it and the shutter. I was much troubled by the rapid decomposition of the potassic permanganate under the influence of the sun's light. When apparently clear to the eye, a lens revealed minute particles which precipitated themselves upon the glass plates of the cell, and gave an appearance of structure to any coronal appearance which was on the plate. Besides, any diminution of the transparency of the solution, by the presence of minute particles would produce scattered light on the plate.

I then tried a solution of iodine in carbon disulphide, but the same inconvenience presented itself. Very soon under the sun's light the solution was found by examination with a lens to show signs of commencing decomposition.

Even when the solution was sensibly clear, there was some disadvantage from unavoidable imperfection of polish of the surfaces of the plates which reveals itself under the strong light in which they are placed. If, however, the violet (pot) glass which I used at first could be obtained annealed and free from the imperfections usually present in it, it would serve most usefully as a selective screen.

For these reasons, after some months' work, I decided to give up the use of absorbing media, and I came to the conclusion that the advantages they present, which are doubtless considerable, are more than balanced by the possible false appearances which they might give rise to if the solutions were not in a condition of perfect transparency.

As, for the reasons stated above, it seemed desirable to avoid placing media of any kind before the sensitive surface, the selective power upon the light had to be sought in the nature of the sensitive surface itself. The suggestion of staining the film presented itself, but after consultation with Captain Abney, I decided to try an emulsion containing silver chloride only. Captain Abney kindly prepared some silver chloride emulsion for me, and the plates were developed with a solution of ferrous-citro-oxalate.

The silver chloride film, according to Captain Abney, is strongly sensitive to light from h to H, and hardly at all beyond H.

Since the middle of July these plates have been used as well as the ordinary silver bromide gelatine plates. A comparison of the two kinds of plates, when used under similar conditions, shows a decided advantage for this work in favour of the silver chloride.

All the plates were backed with a solution of asphaltum in benzole.

For the purpose of screening the sensitive surface from the intensely bright image of the sun, small circular disks of thin brass were turned about $\frac{1}{50}$ inch larger in diameter than the sun's image. The brass disk was held close before the sensitive surface by a fine metal arm when the sun was taken in the middle of the field, and attached to the inner edge of a circular diaphragm when the sun's image was placed towards the side of the field.

A comparison of photographs taken under similar conditions with and without the disk showed less advantage in favour of the disk than was anticipated. Indeed, it may be that, with the short exposures given, the scattered light, which comes upon the plate when the sun's image falls directly on the sensitive surface, may be favourable to the setting up of the photographic action by the comparatively feeble coronal light.

In consequence of the number of diaphragms which it was found

1883 June 6 | 1883. Aug. 20

Illustrating Dr W Huggins's communication, "On some Results of Photographing the Solar Corona without an Eclipse."

W.J. Morley del. | West Newman & Co imp.

Diagrammatic drawing of the main outline features of the Photograph of the Corona taken during the Eclipse of 1883 May 6 at Caroline Island. by Mess[rs] Lawrance and Woods.

Drawn by M[r] Wesley from a positive made by Captain Abney, R.E. F.R.S. by permission of th[e]

desirable to introduce into the apparatus for the purpose of preventing any light but that from the sun and the sky immediately around it from reaching the plate, the extent of field in which the full aperture was in use was small. For this reason it was found of advantage to place the sun's image near the margin of the diaphragm limiting the field, and afterwards to combine the photographs, taken in four different positions.

The moving shutter being placed very near the sensitive surface, and practically in the focal plane, could not give rise to effects of diffraction upon the plate. Besides, the opening in the shutter was never less than half an inch in width, and often as much as an inch or even more, according to the sensitiveness of the plates used.

The most serious difficulty with which I have had to contend has been the absence of clear skies. On many days of bright sunshine the wind has been in a northerly direction bringing here the smoke of London, which produces a whity condition of sky, through which it was obviously hopeless to expect the coronal light to show itself upon the plates.

The few occasions of a better condition of sky were for the most part of short duration and did not allow time for a large number of photographs to be taken.

During the summer about fifty photographs have been obtained, which show photographic action about the sun of a more or less coronal character.

I placed these plates in the hands of Mr. Wesley, who has had very great experience in making drawings from the photographs taken during several solar eclipses, with the request that he would make a drawing for each day on which sufficient photographs had been taken, combining the results of the different photographs in one drawing. This was desirable, as whenever a sufficient duration of sunshine permitted, photographs were taken on silver chloride films, as well as on silver bromide plates; some photographs were taken with the sun screened by the brass disk, others without it; also photographs were taken with the sun in different positions of the field. As a rule, Mr. Wesley has introduced into his drawings those coronal features only which are common to all the plates taken on that day.

The apparatus is attached to the refractor of the equatorial in such a way that the direction of the length of the plate is in that of a parallel of declination; a line, therefore, across the plate is in a direction north and south, and from the date of the photograph the angle of position of the sun's axis can be found. On Mr. Wesley's drawings the orientation is marked, as well as the position of the sun's axis. Four drawings accompany this paper. In most of the negatives more structure than is shown in the drawings is suspected when the plates are carefully examined.

I regretted greatly that on May 6, the day of the solar eclipse, the sky here was very unfavourable. Up to the time of writing this paper I have not seen the photographs taken during the eclipse. Mr. Wesley wishes me to state that he has not seen the photographs or any drawings of the eclipse, and that therefore he has been wholly without bias in making his drawings from my plates. If these drawings are compared with the photographs taken during the eclipse, it should be borne in mind that the absence of sky illumination during the eclipse would allow a larger part of the fainter and more distant regions of corona to be photographed, and that any peculiar conformations or detailed structure of these outer portions could not be expected to be seen on my plates. The comparison

should be restricted to the regions of the corona at corresponding distances from the sun's limb. It is probable that the short exposure eclipse negatives will be found to admit of comparison with my plates better than those exposed for a longer time.

Photographs of the sun have been taken on the days which follow:—

April 2	1 plate	June 6	3 plates
„ 3	1 „	„ 20	1 plate
„ 6	2 plates	July 10	3 plates
„ 26	5 „	„ 15	2 „
May 23	1 plate	Aug. 8	2 „
„ 24	6 plates	„ 13	7 „
„ 31	5 „	„ 20	7 „
		Sept. 4	4 „

All these plates show a more or less distinct coronal appearance about the sun. On some of the days an unfavourable wind brought here the London smoke, which greatly increased the sky illumination relatively to the coronal light which could reach the plate. On these days the photographic action on the plates around the sun, though distinctly coronal in character, possesses less definiteness of form. I entertain the hope that it may be possible, by a careful comparison of all the plates, to gain some information in a general way of the amount, and possibly also of the character, of any large changes of form or of relative brightness which may have taken place in the corona or been due to its motion during the period covered by the observations.

I stated in my paper read before the Royal Society that all I could hope to do in this climate and at the low elevation of my observatory, was to show a method by which, 'under better conditions of climate, and especially at considerable elevations, the corona may be successfully photographed from day to day with a definiteness which would allow of the study of the changes which are doubtlessly always going on in it.' 'Problems of the highest interest in the physics of our sun are connected, doubtless, with the varying forms which the coronal light is known to assume, but these would seem to admit of solution only on the condition of its being possible to study the corona continuously, and so to be able to confront its changes with the other variable phenomena which the sun presents. "Unless some means be found," says Professor C. A. Young, "for bringing out the structures round the sun which are hidden by the glare of our atmosphere, the progress of our knowledge must be very slow, for the corona is visible only about eight days in a century, in the aggregate, and then only over narrow stripes on the earth's surface, and but from one to five minutes at a time by any one observer." '[1]

P.S.—Messrs. Laurance and Woods, the observers sent out at the expense of the Government to photograph the eclipse of May last at Caroline Island, have compared Mr. Wesley's drawings, and the original negatives from which they were made, with the photographs taken during the eclipse. Mr. Laurance, in a letter to Professor Stokes, dated September 14, 1883, says:—

'Dr. Huggins called upon Mr. Woods this morning and showed us the drawings Mr. Wesley has made of his coronas. He told us that he particularly did not wish to see our negatives, but that he would like us to compare his results with ours. We did so, and found that some of

[1] 'The Sun,' p. 289.

the strongly marked details could be made out on his drawings, a rift near the north pole being especially noticeable; this was in a photograph taken on April 3, in which the detail of the northern hemisphere is best shown, while the detail of our southern hemisphere most resembles the photograph taken on June 6; in fact, our negatives seem to hold an intermediate position. Afterwards I went with Dr. Huggins and Mr. Woods to Burlington House to see the negatives. The outline and distribution of light in the inner corona of April 3 is very similar to that on our plate which had the shortest exposure; the outer corona is, however, I think, hidden by atmospheric glare. As a result of the comparison I should say that Dr. Huggins's coronas are certainly genuine as far as 8′ from the limb.'

On Lamé's Differential Equation.

By Professor F. Lindemann, D.Ph.

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

It is known that the integration of Lamé's equation

$$4z(1-z)(1-k^2z)\frac{d^2y}{dz^2}+2[3z^2k^2-2z(1+k^2)+1]\frac{dy}{dz}=[n(n+1)k^2z+h]y$$

has been perfectly settled by Mr. Fuchs and Mr. Hermite for the particular case in which n is a whole number. In all the other cases one can only give the solutions by development in series, each of which is convergent within a circle, whose centre is to be found in a critical point of the above equation (viz., in one of the points $z=0$, $z=1$, $z=k^{-2}$, $z=\infty$), and whose circumference passes through the next critical point; it remains then to establish the relations between the different developments so obtained; e.g., one has in the neighbourhood of the point $z=0$, two integrals of the form

$$y_1=c_0+c_1z+c_2z^2+\ .\ .\ .\ .$$
$$y_2=z^{\frac{1}{2}}[b_0+b_1z+b_2z^2+\ .\ .\ .\ .],$$

and at the point $z=1$, one has the developments

$$y_3=c_0{}^1+c_1{}^1(1-z)+c^1{}_2\ (1-z)^2+\ .\ .\ .\ .$$
$$y_4=(1-z)^{\frac{1}{2}}[b_0{}^1+b_1{}^1(1-z)+b_2{}^1(1-z)^2+\ .\ .\ .]$$

The difficulty which has to be got over is to determine the constants A, B, D, E in such a manner that the equations

$$y_1=\mathrm{A}y_3+\mathrm{B}y_4,\qquad y_2=\mathrm{D}y_3+\mathrm{E}y_4$$

may be satisfied.

Supposing now that $2n$ is a whole number, this problem can be resolved in a remarkably simple way by the same method which I have lately applied[1] to the differential equation of the functions of the elliptic cylinder (i.e., $k=0$). Finally, I have arrived thus at the following result.

[1] *Mathematische Annalen*, vol. xxii. p. 117.

First, designating by y_1, y_2 the two independent particular integrals at the point $z=\infty$ which are given by developments of the form

$$\eta_1=z^{\frac{n}{2}}(\gamma_0+\gamma_1 z^{-1}+\gamma_2 z^{-2}+\ .\ .\ .)$$
$$\eta_2=z^{\frac{-n-1}{2}}(\gamma_0{}^1+\gamma_1{}^1 z^{-1}+\gamma_2{}^1 z^{-2}+\ .\ .\ .),$$

there exists a certain binary quartic

$$f\eta_1{}^4+g\eta_2{}^4+6h\eta_1{}^2\eta_2{}^2=\phi(z),$$

which is a function of rational character, not only at the point $z=\infty$, but also at the point $z=k^{-2}$. Consequently this function is given by one single development convergent in all points without a circle of the radius 1, and with the centre $z=0$; and the convergence is not disturbed by the critical point $z=k^{-2}$. According to a general formula given by Mr. Brioschi,[1] the Hessian covariant, viz., the quartic

$$h(f\eta_1{}^4+g\eta_2{}^4)+(fg-4h^2)\eta_1{}^2\eta_2{}^2$$

is a known function of z also; one has therefore two equations from which the integrals η_1, η_2 may be found.

Secondly, I show that one may obtain two other particular integrals of the form

$$\left.\begin{aligned} y_1&=\mathrm{G}\sqrt{\mathrm{F}(z)}\ \ e^{\mathrm{C}\int\frac{dz}{\mathrm{F}(z)\sqrt{\mathrm{Z}}}} \\ y_2&=\mathrm{G}'\sqrt{\mathrm{F}(z)}\ \ e^{-\mathrm{C}\int\frac{dz}{\mathrm{F}(z)\sqrt{\mathrm{Z}}}} \end{aligned}\right\}\mathrm{Z}=z(1-z)\,(1-k^2z)$$

wherein G, G′ are two arbitrary constants, and C designates another constant chosen in a certain given manner; $\mathrm{F}(z)$ is a function of z given by a development in ascending powers of z, whose convergence is not disturbed by the point $z=1$, but which is convergent for all points within the circle with the radius k^{-2}. This series is found directly as a certain particular integral of that differential equation of the third order, which is satisfied by the quantities $y_1{}^2$, $y_2{}^2$, y_1y_2.

The connection between the functions η_1, η_2, and y_1, y_2 is now given by two relations of the form

$$y_1=\kappa\eta_1+\lambda\eta_2,\quad y_2=\mu\eta_1+\nu\eta_2,$$

wherein the constants κ, λ, μ, ν may easily be determined by choosing for z any point within the circle of the radius k^{-2}, and without the circle of the radius 1.

So one does not need for the integration of the proposed equation but two developments in series (viz., those of the functions ϕ and F), supposing that $2n$ is a whole number.

An exception will present itself when the constant C (entering in the formulæ for y_1 and y_2) is just equal to zero; this is the particular case treated by Mr. Brioschi, *loc. cit.*

It is to be remarked that the formulæ for y_1, y_2 (but not those for η_1, η_2) can be applied whatever the value of n may be.

This seems to me likely to become useful in certain problems relating to the theory of potentials, in a manner that I intend to explain on another occasion.

[1] *Annali di Matematica*, Serie ii., vol. 9, p. 13.

Recent Changes in the Distribution of Wealth in Relation to the Incomes of the Labouring Classes. By Professor LEONE LEVI, *F.S.A., F.S.S., F.R.G.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

§ 1. *Value of Estimates of National Income and National Wealth.*

MANY attempts have been made to arrive at the annual income of the people of the United Kingdom; not, indeed, from any sentiment of vanity or sheer curiosity, but to obtain the necessary data for the appreciation of many economic and social problems of the greatest practical importance. But the problem is difficult to solve, because many branches of income defy any valuation, because different branches of income have not the same value, because such values are subject to constant fluctuations; and because, when we have estimated the income of the different classes of the people, their aggregate will not represent the income of the nation as a whole; the income of one section, as in the case of the professional classes—the domestic service, &c.—being, in reality, the expenditure of another section. All attempts, moreover, to estimate the income of the nation can only be of an approximate character. Enough, indeed, if we can come within a measurable distance of the real truth.

§ 2. *Estimated Amounts of Income and Wealth.*

As far back as in the reign of Henry VIII. a general survey was made of the kingdom, including the number of its inhabitants, their ages, professions, wealth, and other particulars, when the entire income was estimated at 4,000,000*l.*[1] per annum; which, with a population of about 5,000,000, gave a proportion of 16*s.* per head. In 1822, Lord Liverpool valued the income of Great Britain at 250,000,000*l.*; which, with a population of 14,400,000, gave a proportion of 17*l.* per head. In 1854, Mr. M'Culloch[2] estimated the income at 370,000,000*l.*; which, with a population of 21,600,000, gave a proportion of 17*l.* per head. None of these estimates, however, evidently included the incomes of the labouring classes. Of such income there was but little knowledge till 1866, when I began to inquire into, and unite together, their wages and earnings, and found them amounting to upwards of 400,000,000*l.* per annum. In 1868, Mr. Dudley Baxter gave his valuable paper on national income; and he estimated the total amount for the United Kingdom at 814,000,000*l.*; which, on a population of 30,000,000, gave a proportion of 20*l.* 17*s.* per head. And in 1881, the population being about 35,000,000, the income has been estimated at 1,000,000,000*l.* per annum, or 28*l.* per head. In a similar manner, calculations have been made of the capital of the State. Gregory King, in 1688,[3] estimated the total value of England at 650,000,000*l.* Dr. Becke, in 1798, estimated the capital at 995,000,000*l.*; and in the same year, Mr. Pitt estimated it at

[1] Dr. Colquhoun, *Wealth, Power, and Resources of the British Empire*, p. 148, 1815.

[2] M'Culloch, *Account of the British Empire*, vol. ii. p. 526.

[3] *Natural and Political Observations upon the State and Condition of England*, 1696.

1,125,000,000*l.* In 1812 Dr. Colquhoun [1] estimated the capital value of the United Kingdom at 2,700,000,000*l.* In 1842 Mr. Porter [2] estimated the amount of personal property at 2,200,000,000*l.*, and of real property 2,382,000,000*l.*; total, 4,582,000,000*l.* And in 1878 Mr. Giffen estimated it at 8,500,000,000*l.*[3]

But these varied estimates are not strictly comparable, however useful they may be as recording the results arrived at at different times by earnest and *bonâ fide* labourers in statistical science. We do not know the method pursued by each, or whether the income of every class of the community has been duly computed in each case. If we compare the income of the people of the United Kingdom at the extreme periods embraced, making allowance for the altered value of money and the difference in the purchasing power, the economic progress, however large, thereby indicated, may easily be accounted for. But if we compare each estimate with the preceding one, the results present some decided anomalies. Recent estimates have certainly the advantage of the income-tax assessments, which represent the amount for which the persons subject to the tax are willing to be rated. And though there may be, in many cases, the temptation to under-estimate that income so as to escape the tax in all or in part, still, on the aggregate, the range of error is considerably less by this method than by other modes of valuation.

§ 3. *Changes in the Distribution of Wealth.*

The purpose of this paper, however, is not to examine critically the estimates already made of the income of the people of the United Kingdom, nor to offer any exhaustive estimate of my own. For this purpose, the forthcoming volumes of the 'Report on the Census of 1881' will supply most valuable materials; and I hope to avail myself of the same for a paper for the forthcoming meeting of the Association at Montreal. What

[1] See Dr. Colquhoun's work, p. 55.

[2] *Progress of the Nation.*

[3] Estimates of a like character have also been made in France, Germany, Austria, and the United States of America:—

Germany and Austria.—Neumann-Spällart, *Uebersichten über Produktion, Verkehr und Handel in der Weltwirthschaft*, 1878; Michaelis, *Die Gliederung der Gesellschaft nach dem Wohlstande*, Leipzig, 1878; Soetbeer, *Umfang und Vertheilung des Volks-Einkommens im Preussischen Staate*, Leipzig, 1879.

France.—Vauban, *Projet d'une dîme royale*, Paris (Guillaumin), 1843. Vol. i. of the *Economiste financier du XVIII. siècle*; Lavoisier, *De la richesse territoriale de la France*, Paris (Guillaumin), 1847. *Mélange d'économie politique* (by E. Daire and G. De Molinari); Lagrange, *Essai d'arithmétique politique sur les premiers besoins de l'intérieur de la République* (*ibid.*); Block, *Statistique de la France*, Paris, 1878; *Dictionnaire de la politique*, 2de éd. Paris, 1875, art. 'France'; Mony, *Étude sur le travail*, Paris, 1877; Vacher, 'La fortune nationale de la France,' *Journal de la Société de Statistique de Paris*, Nov. 1878; De Foville, 'De quelques évaluations récentes du capital national,' *Economiste français*, December 28, 1878, and January 28, 1879.

England.—Porter, *On the Progress of the Nation*, London, 1847; Capps, *The National Debt Financially Considered*, London, 1859; Levi, *On Taxation*, London, 1860; Dudley Baxter, *National Debt*, 1871. *National Income*, 1868; Giffen, 'Recent Accumulation of Capital in the United Kingdom,' *Journal of the Statistical Society*, March 1878; Newmarch, *On the Progress of the Foreign Trade of the United Kingdom since* 1856; June 1878.

Essai sur la question d'une statistique de revenu national (Commission permanente du Congrès International de Statistique), Mémoire, 1876.

Annali di Statistica, vol. 15, 1880. 'Proposal of Professor Salandra for a Calculation of National Wealth in Italy.'

I aim at is to elicit from the materials now at hand some indication of the recent changes in the distribution of property, more especially in relation to the estimated income of the labouring classes. Within the last thirty years great changes have taken place in the economic condition of the people. The introduction of free trade—or, more correctly stated, a more economic financial and commercial policy—the great extension of railways, the discoveries of gold in California and Australia, the enjoyment of a lengthened period of comparative peace, and the development of resources in the British colonies and dependencies, have each and all had surprising effects on the trade and industries of the realm. Have the higher, middle, and labouring classes participated in the same proportion in the increasing wealth of the nation?

§ 4. *Classification of the Population.*

It is difficult to classify the population under any well-defined categories. Generally, we have the broad distinction between income taxpayers and non-income taxpayers. But the number of income taxpayers at any time is affected by the changes made in the limit of incomes subject to the tax. In 1798 the tax was levied upon all incomes of 60*l.* and upwards. Since 1875–6 the tax has been levied only upon incomes of 150*l.* and upwards, subject to certain allowances or abatement of duty. Non-income taxpayers, on the other hand, comprise the lower middle class and the labouring classes. The more common distinction of society is the division into the higher, middle, and lower classes. But who are the higher classes? Shall we place within this category the large landowners only, or shall we include among them those having large incomes from whatever sources? Who are the middle classes? There is a higher middle and a lower middle class. Our merchants and bankers pride themselves on being the great middle class. But so are clerks, teachers, and ministers of religion, having but a small annual income; whilst it is a misnomer to distinguish any number of persons as working classes when we are all workers, some with the hand, some with the mind, and many with both. Moreover, the so-called working classes include artisans, labourers, domestic servants, &c., &c. Practically we have four classes of society: first, we may take the aristocracy of wealth including all having an income of 3,000*l.* and upwards; second, the middle class, those having an income of 500*l.* to less than 3,000*l.*; third, the lower middle class, those having an income of 150*l.* and less than 500*l.*; and fourth, we have the lower professional or trading classes, and the labouring classes, having an income of less than 150*l.*

§ 5. *Assessed Incomes of the Middle and Higher Classes*, 1851 *and* 1881.

Let us now see what light the Income Tax Returns throw on the distribution of income among those so assessed in 1851 and 1880 respectively. An exact comparison, indeed, cannot be made; for, whilst the classification under Schedule D in 1851 included the incomes of public companies except mines, quarries, ironworks, gasworks, railways, waterworks, canals, &c., which were not assessed under Schedule D until 1866–67, the classification for 1879–80 includes trade and professions only. Still, the comparison in so far as regards the relative incomes at the two periods may be useful. The return relating to Schedule D refers to Great Britain, and for the years 1850–51 and 1879–80, is as follows:—

Incomes	1850–51 Number assessed	1850–51 Amount assessed	1850–51 Per cent. of number	1850–51 Per cent. of amount	1879–80 Number assessed	1879–80 Amount assessed	1879–80 Per cent. of number	1879–80 Per cent. of amount
Middle Classes.		£				£		
£150 to £200	39,475	6,217,000	35·73	12·01	144,158	22,636,000	40·84	15·10
200 to 300	29,389	6,487,000	26·60	12·47	97,410	21,607,000	27·60	14·43
300 to 400	14,399	4,605,000	13·03	8·85	43,556	13,822,000	12·32	9·22
400 to 500	6,968	2,943,000	6·31	5·65	18,059	7,493,000	5·11	5·00
	90,231	20,282,000	81·67	38·98	303,183	65,558,000	85·89	43·75
Higher Middle Classes.								
500 to 600	5,119	2,638,000	4·63	5·07	12,364	6,324,000	3·50	4·23
600 to 700	2,851	1,768,000	2·58	3·39	7,498	4,597,000	2·12	3·06
700 to 800	1,932	1,405,000	1·74	2·70	4,474	3,233,000	1·27	2·16
800 to 900	1,594	1,306,000	1·44	2·51	3,898	3,176,000	1·10	2·11
900 to 1,000	789	731,000	·71	1·45	1,605	1,482,000	0·45	0·98
1,000 to 2,000	4,708	6.098,000	4·26	11·72	11,495	14,692,000	3·26	9·81
2,000 to 3,000	1,342	3,108,000	1·22	5·97	3,474	7,962,000	0·98	5·32
	18,335	17,051,000	16·58	32·81	44,808	41,466,000	12·68	27·67
Higher Classes.								
3,000 to 4,000	625	2,070,000	·56	3·97	1,600	5,284,000	0·45	3·54
4,000 to 5,000	338	1,446,000	·36	2·78	861	3,731,000	0·24	2·49
5,000 to 10,000	588	3,993,000	·53	7·67	1,601	10,594,000	0·45	7·07
10,000 to 50,000	312	5,289,000	·28	10·47	910	16,056,000	1·26	10·72
50,000 and upwards	26	1,880,000	·02	3·62	77	7,126,000	0·02	4·76
	1,889	14,678,000	1·75	28·51	5,052	42,791,000	1·43	28·58
Total . .	110,455	52,014,000	100·00	100·00	353,043	149,835,000	100·00	100·00

Some interesting facts may be gathered from this table. First, that the average amount of assessments of incomes 150*l*. and upwards in Schedule D per person was 424*l*. in 1880, against 470*l*. in 1851, indicating greater diffuseness of incomes side by side with a larger total. Secondly, that a larger proportion, viz., 85·6 per cent. in 1881, against 80·9 per cent. in 1850–51—are now assessed with the lower incomes than with the larger; and, thirdly, that a larger proportion of the amount—viz., 43 per cent. in 1880, against 38 per cent. in 1881—is assessed on the lower incomes than on the higher.

Comparing the proportion of persons assessed with the population of Great Britain at the respective periods—viz, 20,900,000 in 1851, and 29,800,000 in 1881—the following are the results:—

Income	Number assessed per 1,000,000 inhabitants				Increase per cent.
	1850-1		1879-80		
	Schedule D	All Income Taxpayers	Schedule D	All Income Taxpayers	
Middle Classes.					
£150 to £200	1,900	5,700	4,800	14,400	152
200 to 300	1,380	4,140	3,233	9,699	136
300 to 400	660	1,980	1,466	4,398	122
400 to 500	333	999	600	1,800	80
	4,273	12,819	10,099	30,297	136
Higher Middle Classes.					
500 to 600	101	303	412	1,236	308
600 to 700	135	405	250	750	85
700 to 800	92	276	150	450	63
800 to 900	76	228	130	390	71
900 to 1,000	37	111	53	159	43
1,000 to 2,000	224	672	383	1,149	71
2,000 to 3,000	64	192	115	345	79
	729	2,187	1,493	4,479	104
Higher Classes.					
3,000 to 4,000	29	87	53	159	82
4,000 to 5,000	16	48	28	84	75
5,000 to 10,000	28	84	53	159	96
10,000 to 50,000	15	45	30	90	100
50,000 and upwards	1	3	2	6	100
	89	267	166	498	86
Total . .	5,091	15,273	11,758	35,274	133

Absolutely, as well as in proportion to population, there has been a greater increase in the number of persons in the receipt of the lower than of the higher incomes. These facts apply only to incomes from industry, yet there is reason to believe that they represent the condition of all descriptions of incomes. In a note in the appendix to Mr. Dudley Baxter's paper on national incomes, by Mr. Gripper, of the Inland Revenue, it is stated that the number of income taxpayers under Schedule A may be taken to be divided in the same proportion as under Schedule D; and that the same may be said as to Schedules B, C, and E. Assuming this

to be true, it is a significant fact that whilst the number of persons in the receipt of incomes from 150*l.* to 500*l.* increased in the thirty years at the rate of 136 per cent., the number of persons in the receipt of incomes of 3,000*l.* and upwards increased only at the rate of 86 per cent.

§ 6. *Relation of Land to other Sources of Wealth.*

It has been asserted in Mr. Henry George's work on 'Progress and Poverty,' that the effect of an increasing population upon the distribution of wealth is to increase rent, and consequently to diminish the proportion of the produce which goes to capital and labour; and that the reason why, in spite of the increase of productive power, wages constantly tend to a minimum which gives but a bare living, is that with the increase of productive power rent tends to even greater increase, thus producing a constant tendency to force down wages. What has been the proportion of rent of land to the total income of the nation? Have landowners and farmers flourished, and the rest of the people decayed? Let the following comparison of facts answer the question:—

Years	Incomes from land and tithe. Schedule A	Income of farmers. Schedule B	Total	Total gross income assessed	Per cent. of Schedules A and B to total income
	£	£	£	£	
1814–5	39,405,000	38,396,000	77,801,000	137,621,000	56
1851	47,800,000	48,000,000	95,800,000	257,000,000	37
1880	69,300,000	69,200,000	138,500,000	577,000,000	24

The proportion of national income derived from land was therefore considerably less in 1880 than in 1814–5. Who are the real aggressors on the wealth of the country? The landowners have evidently much difficulty in keeping their own, from the decreasing value of land and the inroad of wealthy merchants as purchasers of some of the choicest estates in the market, whilst land companies greatly promote the diffusion of landed property. I shudder to think what a large proportion of the landed property is now mortgaged to the utmost limit of its value. House property has greatly augmented in value. In 1851 the value assessed on houses in Great Britain was 42,978,000*l.*; in 1881 the value so assessed was 117,465,000*l.* But house property is greatly divided, and building societies have extended the ownership of houses among the labouring classes.

§ 7. *Incomes of the Lower Middle Classes.*

Whatever may have been the increase in the number of persons having comparatively larger incomes, there is reason to believe that a proportionate improvement has also taken place in those immediately below the limit of the income-tax range. Of the lower middle class of life, the teacher and the clergyman are the fittest representatives. Of the income of teachers we have some well-ascertained evidence in the reports of the Committee of Council on Education. Comparing 1855 with 1881, the incomes of certificated masters were as follows:—

Masters	Average amount of salaries of certificated teachers 1855	1881	Per cent. increase
	£ s. d.	£ s. d.	
Church of England . .	87 19 3	114 8 10	29
British Schools . . .	101 16 7	132 3 3	29
Roman Catholics . .	75 12 5	99 15 0	32
	88 6 0	115 0 0	30
School Board Schools .	—	125 13 0	43

The economic condition of teachers has, therefore, immensely improved within the last twenty-five years. Of the income of clergymen I have few reliable facts, but we know that considerable efforts have been made, and with tolerable success, to increase the stipends of curates, whilst in every religious community the learning and piety of their religious teachers are better appreciated and remunerated. An evidence of this may be given in the rise which has taken place in the stipends of ministers in a comparatively small church—the Presbyterian Church of England. In 1866 the average stipend of its ministers was 213*l.* In 1883 their stipends had risen to an average of 310*l.*, showing an increase of 45 per cent. The income of commercial and banking clerks may be taken to have increased about 15 per cent., and from facts contributed by two important houses, I learn that the higher salaries of heads of departments have increased considerably more. I have no data to estimate what rise has of late taken place in the income of small shopkeepers, but judging from the houses they live in, and the rate of their household expenditure, their position must have improved in full proportion to the economic improvement of the people. Nor must I forget the increasing facilities now open to girls and women of the lower middle classes in the Civil Service and other professions to earn at least sufficient for their own maintenance, and so diminish the burden of their parents. Taken altogether, if the average income of the lower middle classes was 90*l.* in 1851, we may fairly take it in 1881 at 110*l.* per family.

§ 8. *Incomes of the Labouring Classes.*

The income of the labouring classes is determined by the wages prevailing in agriculture, building, the manufacturing districts, mining, and in domestic service. Extensive data upon each of these different branches of labour would be necessary in order to estimate carefully the average rise over the whole field. But a few well-recorded facts may be given. In Mr. Coleman's Report on Agriculture in Northumberland, appended on the Report of the Royal Commission on Agriculture, the single hind's wages per week is given as follows:—

	Wages per week		Wages per week
	s. d.		s. d.
1851	11 0	1871	16 6
1861	16 6	1881	18 0

—showing an increase from 1851 to 1881 of 63 per cent. In Shropshire the price of labour in agriculture was reported as follows:—

	Price of mowing an acre of grass	Price of hoeing an acre of turnips	Price of reaping an acre of corn
1862	3*s.* to 4*s.*	5*s.* to 5*s.* 6*d.*	9*s.* to 10*s.*
1880	4*s.* to 7*s.* 6*d.*	5*s.* 6*d.* to 11*s.*	13*s.* to 15*s.*

In the wages of builders there have been great oscillations. Nominally, the wages of masons, carpenters, &c., have been for some time in London 9*d.* per hour; but this rate is by no means uniform, and in the country 6½*d* to 7*d.* per hour is commonly the rate. Although the rise which took place in 1882 in building wages has not been uniformly sustained, the position of the building classes has greatly improved, especially where they work by the piece. The wages in the cotton manufacture, as given by Mr. Chadwick in the Journal of the Statistical Society, and by Dr. Watt in the last edition of the 'Encyclopædia Britannica,' have progressed as follows:—

	1850	1860	1865	1876
	Per week	Per week	Per week	Per week
	s.	*s.*	*s.*	*s.* *s.*
Spinners (men)	20	27	30	35 to 40
Carders	20	28	35	32 to 40
Grinders	14	17	26	25 to 28

In a return produced by Mr. George Lord, President of the Manchester Chamber of Commerce, of the increase of the wages earned in the various trades in Lancashire between the years 1850 and 1883, the total average advance in cotton spinning and weaving, cotton spinning, fine cotton spinning and weaving, bleaching and calico printing, is given at 42 per cent.

And we all know how much the wages of domestic servants have increased. A woman-servant who was content with 10*l.* per annum in 1851, now gets at least 14*l.*; and all other descriptions of servants in the same proportion. Not only, however, are the direct wages of working men and women greatly increased of late, but with the extension of piece-work in most industries, their earnings have in many cases become much greater. And, what is more, the income of women and children has greatly increased. Altogether the rise of wages and earnings in all branches of labour has been considerable within the last thirty years, and the income of the workman's family, including every earner in the same, and including the interest on accumulated incomes in the savings bank and other forms, is considerably greater now than in former years. If, therefore, the income of a working man's family in 1851 could fairly be estimated, on the whole number, at 20*s.* a-week, or 52*l.* a-year, the total income of a working man's family in 1881, including the value of perquisites, food, house rent, and clothing, whenever given, may fairly be taken at 32*s.* per week, or 83*l.* per annum.

§ 9. *Population and Incomes in* 1851 *and* 1881.

With these facts before us, let us endeavour to take a general view of the income of the people in 1851 and 1881, bearing in mind that the population of the United Kingdom was 27,700,000 in 1851, and 35,200,000 in 1881. The return of the number of persons charged to income tax refers only to those deriving income from trade and professions. How

shall we arrive at the number paying income tax under the other schedules? As I have already stated, Mr. Gripper, of the Inland Revenue, in a note on the number and average income of income taxpayers in England and Wales, appended to Mr. Dudley Baxter's paper on national income, arrived at the conclusion that the number of persons charged under Schedule D being then 297,000, the total number of income taxpayers could be taken at 900,000, or three times as many. Adopting this method, we come to the conclusion that the 110,000 persons charged with income tax under Schedule D in 1850–51, with incomes of 150*l*. and upwards, would represent 330,000 as the entire number of income taxpayers; and that the 353,000 similarly charged in 1879–80 under Schedule D would represent 1,059,000 as the whole number of income taxpayers. Now multiply these numbers by four and a half to a family, and we have 1,500,000 in 1850–51, and 4,700,000 in 1879–80, as embraced within the income taxpaying population. On the other side of the scale, we have the great body of the labouring classes, embracing 70 per cent. of the entire population, or 19,300,000 persons, representing 4,300,000 families, in 1851, and 24,600,000 persons, or 5,400,000 families, in 1881. Take the difference between these two sets of figures, and we have the lower middle classes—viz., 6,900,000 persons, or 1,500,000 families, in 1851, and 5,900,000 persons, or 1,300,000 families, in 1881.

Now place against these numbers the income of each class at the respective period, adding 6 per cent. for the probably assessable income for Ireland in 1851, not then within the Income Tax, and we have the following results:—

	Number of persons	Number of families	Total gross income	Income per family	Proportion per cent.
1851.					
			£	£	
Income taxpayers	1,500,000	330,000	272,000,000	824	44
Lower middle class	6,900,000	1,500,000	120,000,000	80	20
Labouring classes	19,300,000	4,300,000	224,000,000	52	36
	27,700,000	6,130,000	616,000,000	£100	100
1879–80.					
Income taxpayers	4,700,000	1,060,000	577,000,000[1]	544	49
Lower middle class	5,900,000	1,300,000	143,000,000	110	12
Labouring classes	24,600,000	5,400,000	448,000,000	83	39
	35,200,000	7,760,000	1,168,000,000	£150	100

[1] In 1882–83 the sum assessed was £601,450,000.

If we now compare the income of these classes of society in 1851 and 1881 we have their rate of progress as follows :—

	1851	1881	Increase per cent.	Decrease per cent.
	£	£		
Income taxpayers . .	824	544	—	30
Lower middle classes .	80	110	37	—
Labouring classes . .	52	83	59	—
	100	150	42	

It may seem bold to reduce to a numerical ratio the relative condition of the different classes of society; nevertheless, we have here a clear evidence that the labouring classes have participated to the full in the tide of prosperity which the nation has enjoyed for the last thirty years, and a tangible proof that the increase of commerce and manufactures has not only introduced into the community a powerful middle class, but has actually increased considerably the income of the labouring population. In truth, with prosperous trade, we have progress all along the line.

§ 10. *Progress and Poverty.*

Mr. Henry George's work on progress and poverty is able and ingenious; but the arguments produced do not stand the test of economic science. Still less reliable or economic, however, is the programme of the Democratic Federation recently issued, including as it does, among other things, the State appropriation of railways, the practical repudiation of the National Debt, and the nationalisation of land. Believe me, there is no short cut in the road to wealth. Let us not deceive ourselves with illusory statements or fanciful doctrines. Make Socialism ever so plain, and it will be found to rest on the negation of the right of property, which is the best incentive to the employment of labour, and on the possibility of an equal division of wealth, which is incompatible with the endless variety of powers and talents of men, and the ever-shifting circumstances of life. All facts recording the economic progress of every class of the people in the United Kingdom bear ample testimony to the truth of economic axioms; and our labouring classes are too intelligent to imagine they can set them at nought, or that they would benefit by the attempt to do so. They know, moreover, that by the working out of economic problems, the financial administration of late years has been altogether in their favour, for, while the taxes on general comforts, such as corn, tea, sugar, coffee, &c., have been either altogether relaxed, or greatly reduced, the taxes on extravagance, as on spirits, tobacco, and wine, have become much more productive. It is, moreover, a source of great comfort to find that, whilst in 1851 the amount held by the savings banks was 30,000,000*l.*, in 1882 it reached 84,000,000*l.* Allowing that the amount held by the savings banks belongs to the lower middle and labouring classes alike, it follows that, whilst in 1851 the

amount so held averaged 1*l.* 2*s.* 10*d.* per head, in 1882 it averaged 2*l.* 15*s.*, showing an improvement of 139 per cent.[1]

§ 11. *Relative Improvement of different Classes of Society.*

The relative condition of classes in the United Kingdom is by no means immutable. Wealth is attainable by labour and economy, and no class is shut out from the competition. Nay, more, under the British political system there is no right, no advantage, and no avenue to honour, which is not free and open to all alike. Let there be only perseverance and economy, talent and wisdom, self-mastery and self-restraint, honour and virtue, and the ascent from the lowest to the highest rank, though often rugged and steep, is barred to no one. What is it that the labouring classes should really aim at? Release from labour? A greater amount of political power? Ah, no! The true elevation of the labouring man consists in an increasing energy of his thinking powers, a greater force of moral purpose, a greater culture of the intellect, a greater refinement of manner and taste, above all in an increasing capacity to repel what is depressing and to attract what is ennobling in his daily intercourse of life.

[1] *The British Revenue in* 1842 *and* 1882.

	1842	1882	Increase	Decrease
	£	£	Per cent.	Per cent.
Taxes on Luxuries: Beer, Spirits, Tobacco, Wine	18,100,000	37,300,000	106	—
Taxes on General Comforts: Tea, Sugar, Coffee, Corn, and others	15,800,000	4,800,000	—	69
Taxes on Land, Houses, and Employments	5,800,000	6,600,000	13	—
Taxes on Industries: Paper, Hops	3,200,000	800,000	—	—
Taxes on Transfer of Property Stamps	7,300,000	11,300,000	68	—
Revenue from Income and Property Tax	—	9,900,000	—	—
„ Post Office and Telegraph	1,400,000	8,600,000	514	—
„ Other branches	600,000	5,700,000	—	—
Total Revenue	52,200,000	85,000,000	—	—

APPENDIX.

Income Tax. Schedule D.

Return giving the Number of Persons and Gross Amount of Profits assessed under Schedule D in Great Britain, distinguished in the following Classes for the Years 1850–1 *and* 1879–80.[1]

	Great Britain				
	1850–51.[2]		1879–80.[3]		
	Number	Gross Amount assessed	Number	Gross Amount assessed	
		£		£	
£100 to £150, but not exempt.	33,867	2,510,828	45,792	4,309,788	Under £150, but not exempt.
150 to 200	39,475	6,247,277	144,158	22,636,446	150 to 200
200 „ 300	29,389	6,487,327	97,410	21,607,602	200 „ 300
300 „ 400	14,399	4,605,167	43,556	13,821,549	300 „ 400
400 „ 500	6,968	2,942,631	18,059	7,492,711	400 „ 500
500 „ 600	5,119	2,638,215	12,364	6,323,612	500 „ 600
600 „ 700	2,851	1,767,978	7,498	4,597,229	600 „ 700
700 „ 800	1,932	1,405,372	4,474	3,232,729	700 „ 800
800 „ 900	1,594	1,305,509	3,898	3,175,785	800 „ 900
900 „ 1,000	789	730,670	1,605	1,482,255	900 „ 1,000
1,000 „ 2,000	4,708	6,097,786	11,495	14,692,200	1,000 „ 2,000
2,000 „ 3,000	1,342	3,108,302	3,474	7,962,096	2,000 „ 3,000
3,000 „ 4,000	625	2,070,526	1,600	5,284,754	3,000 „ 4,000
4,000 „ 5,000	338	1,446,531	861	3,731,024	4,000 „ 5,000
5,000 „ 10,000	588	3,993,335	1,604	10,594,777	5,000 „ 10,000
10,000 „ 50,000	312	5,289,076	910	16,056,337	10,000 „ 50,000
50,000 and upwards.	26	1,879,794	77	7,125,916	50,000 and upwards.
	144,322	54,526,324	398,835	154,126,810	

[1] The following return has been most kindly contributed by the Commissioners of the Inland Revenue. It differs from the corresponding returns in the 13th and 24th Reports of that Board in the fact that the amount given in this return is the amount *assessed*, whilst the amount given in these returns is the amount *charged* to income tax. The difference between the two is considerable as regards all incomes subject to abatements and allowances.

[2] This classification includes the incomes of public companies, except mines, quarries, ironworks, gasworks, railways, waterworks, canals, &c., which were not assessed under Schedule D until 1866–67.

[3] This classification includes trades and professions only, there being no similar classification of public companies on record. The amount for such public companies as it is assumed were included in the classification for 1850–51, was, for the year 1879–80, 30,470,000*l.*

Gross Amount of Property and Profits under all Schedules in Great Britain in the Years 1850–1 *and* 1879–80.

1850–51 . .	£257,392,723 . .	Great Britain
1879–80 . .	£540,756,324 . .	„
	36,140,577 . .	Ireland
Total . .	£576,896,901 . .	United Kingdom

Return showing the increase of the wages earned in various trades in Lancashire between the years 1850 and 1883:—

TABLE I.—*Cotton Spinning and Weaving—Medium Quality.*

Description	Male or female	Wages earned weekly in 1850	Wages earned weekly in 1883	Average percentage increase in each trade between 1850 and 1883
		s. d.	*s. d.*	
Strippers and Grinders	M.	10 6	21 0	74·72
Rovers	F.	7 6	18 0	
Throstle Spinners	F.	7 6	15 0	
Minders	M.	12 6	25*s.* to 28*s.*	
Winders	F.	7 0	17 6	
Weavers	M. & F.	14 0	19 6	
Mechanics	M.	23 6	32 0	
Overlookers and Tacklers	M.	22 0	36*s.* to 38*s.*	
Stone Masons	M.	20 0	30 0	
Labourers	M.	12 0	22 0	
Percentage increase on 1850	—	—	74·72	

TABLE II.—*Cotton Spinning—Fine.*

Description	Male or female	Wages earned weekly in 1850	Wages earned weekly in 1883	Average percentage increase in each trade between 1850 and 1883
		s. d.	*s. d.*	
Spinners—Hand-mules	M.	38 0	40 0	16·27
Cyphers	M.	11 0	16 0	
Piecers	F.	6 6	11 0	
Creelers	F.	5 8	7 0	
Mechanics	M.	30 0	32 0	
Percentage increase on 1850	—	—	16·27	—
Drawing Tenters	F.	*No return	10 6	—
Jack Tenters	F.	*No return	10 0	—
Grinders	M.	*No return	23 6	—
Minders—Self-actors	M.	*No return	38 0	—

* For these years no returns have been made, but the difference is so slight that it would not affect the general average from which these items have been excluded.

NOTE.—Hours of labour to 1874. 60 hours per week.
" " from 1874. 56½ " "

TABLE III.—*Fine Spinning and Weaving.—Bolton.*

Description	Male or female	Wages earned weekly in 1850	Wages earned weekly in 1883	Average percentage increase in each trade between 1850 and 1883
		s. d.	s. d.	
Strippers and Grinders	M.	10 0	21 0	35·16
Rovers	F.	6 8	16 0	
Minders	M.	43 0	46 0	
Winders	F.	9 0	11 6	
Weavers	M. & F.	4 7 per loom	5 6	
Mechanics	M.	25 0	35*s.* to 38*s.*	
Tacklers	M.	29 0	35 6	
Percentage increase on 1850	—	—	35·16	

TABLE IV.—*A very large Cotton Mill, Spinning No.* 150 *Weft.*

Description	Male or female	Wages earned weekly in 1850 Per 60 hours	Wages earned weekly in 1883 Per 56 hours	Increase per cent.
		s. d.	s. d.	—
Labourers	—	15 6	20 0	—
Mechanics	—	27 0	33 0	—
Strippers and Grinders	—	13 6	21 0	—
Cardroom Overlookers	—	27 0	32 0	—
Roving Frame Tenters	—	8 3	14 0	—
Drawing Tenters	—	8 3	11 0	—
Combing Tenters (1853)	—	8 6	15 6	—
Jack Tenters	—	8 0	16 6	—
Spinners (hand)	—	40 0	52 0	—
Big Piecers	—	13 0	16 0	—
Spinners (self-actors)	—	—	42 0	—
		168 6	231 0	37 %

NOTE.—Hours of labour to 1874. 60 hours per week.
" " from 1874. 56½ " "

TABLE V.—*Fine Spinning.—Bolton.*

Description	Male or female	Wages earned weekly in —	1883	
			s. d.	
Strippers and Grinders . .	M.	—	24 0	
Jack Tenters	F.	—	15 11	
Drawing Tenters . . .	F.	—	14 9	
Self-actor Minders . . .	M.	—	32 2	
Piecers—big	M.	—	13 0	
„ little	M.	—	8 9	
Average increase in 1883 on 1864	—	—	31·26%	

NOTE.—As this return is not for the same years as the others, it is not included in the General Summary.

NOTE.—Hours of labour to 1874. 60 hours per week.
„ „ from 1874. 56½ „ „

TABLE VI.—*Bleaching.*

Description	Male or female	Wages earned weekly in 1850	1883	Average percentage increase in each trade between 1850 and 1883
		s. d.	s. d.	
Dressers or Singers . . .	M.	31 6	39 1	
Hand Crofters	„	27 5	32 1	
Bleaching Machine—Foremen	„	21 9	34 0	
„ „ Minders .	F. say	7 0	9 3	
„ „ Pumpers.	„ say	6 0	6 10	
„ „ Plaiters .	„	5 2	5 11	
Stiffeners	M.	29 8	75 9	
Assistant Stiffeners . . .	„	23 0	25 0	50%
Manglers	„	21 11	28 8	
Calenderers	„	22 2	30 9	
Driers	„	19 8	27 9	
Makers-up	„	18 5	32 8	
Hookers (age 16) . . .	M. & F.	5 7	12 3	
Packers	M.	19 7	28 3	
Percentage increase on 1850	—	—	50·00	

TABLE VII.—*Calico Printing.*

Description	Male or female	Percentage advance on 1850: 1850	1883	Average percentage increase in each trade between 1850 and 1883
Machine Printers . . .	M.	—	50%	50%

TABLE VIII.—*Shipping Warehouse.*

Description	Male or female	Wages earned weekly in 1850	Wages earned weekly in 1883	Average percentage increase in each trade between 1850 and 1883
		s. d.	s. d.	
Hookers	M.	6 0	12 0	34·02
Makers-up	"	26 0	33 0	
Packers	"	26 0	32 0	
Cloth-lookers	"	15 0	20 0	
Engineers	"	24 0	34 0	
Percentage increase on 1850	—	—	35·05	

TABLE IX.—*Mechanical Engineering.*

Description	Male or female	Wages earned weekly in 1850	Wages earned weekly in 1883	Average percentage increase in each trade between 1850 and 1883
			s. d.	
Fitters	M.	Assumed to be same as in 1860.	32 0	10·30
Turners	"		32 0	
Boilermakers	"		32 0	
Smiths	"		33 0	
Moulders	"		36 0	
Labourers	"		17 0	
Percentage increase on 1850	—	—	10·30	

TABLE X.—*Coal Mining.*

Description	Male or female	Wages earned weekly in 1850	Wages earned weekly in 1883	Average percentage increase in each trade between 1850 and 1883
		s. d.	s. d.	
Colliers	M.	19 6	26 3	43·53
Engineers	"	18 5	32 6	
Smiths	"	23 6	29 4	
Joiners	"	21 3	30 5	
Carters	"	15 4	18 2	
Draymen	"	14 3	21 2	
Dischargers	"	16 4	20 2	
Bricklayers	"	18 10	33 7	
Percentage increase on 1850	—	—	43·53	

TABLE XI.—*Building.*

Description	Male or female	Wages earned weekly in 1850		Wages earned weekly in 1883		Average percentage increase in each trade between 1850 and 1883
		s.	*d.*	*s.*	*d.*	
Joiners	M.	24	0	36	4	39·76
,, Labourers	,,	17	0	22	8½	
Bricklayers	,,	26	0	38	7	
,, Labourers	,,	17	0	25	0	
Masons	,,	24	0	32	8	
,, Labourers	,,	17	0	20	5	
Plasterers	,,	26	0	36	4	
,, Labourers	,,	17	0	22	9	
Percentage increase on 1850	—	—		39·76		

TABLE XII.—*Iron Manufacture.*

Description	Male or female	1850 *s.*	1850 *d.*	1883 *s.*	1883 *d.*	
Puddlers	M.	45	0	48	0	Decrease 14·88
Hammermen	,,	70	0	65	0	
Forge Rollers	,,	50	0	50	0	
Ball Furnacemen or Heaters	,,	60	0	50	0	
Wire Rollers	,,	120	0	120	0	
,, Drawers	,, say	80	0	45	0	
Galvanizers	,,	80	0	40	0	
Mechanics	,,	28	0	31	0	
Labourers	,,	18	0	20	0	
Percentage *decrease* on 1850	—	—		14·88		

SUMMARY.

Description	Percentage increase in wages earned in the under-noted years on those earned in 1850			
	1860	1870	1877	1883
Cotton Spinning and Weaving—Medium	16·85	43·59	64·47	74·72
Cotton Spinning—Fine	Unchanged	9·68	30·21	16·27
Cotton Spinning and Weaving—Fine—Bolton	Ditto	15·13	37·72	35·16
Ditto No. 150 weft	No returns	No returns	No returns	37·00
Bleaching	32·06	31·40	56·60	50·00
Calico Printing	8·00	25·00	50·00	50·00
Shipping Warehouse	15·46	25·77	31·44	35·05
Mechanical Engineering	Unchanged	2·42	12·73	10·30
Coal Mining	22·78	24·64	55·64	43·53
Building	10·12	23·11	48·21	39·76
Average advance	11·70	22·30	43·00	39·18
	9 trades	9 trades	9 trades	10 trades
Iron Manufacture—Decrease	8·71	11·98	10·16	14·88

GEORGE LORD, *President.*

MANCHESTER CHAMBER OF COMMERCE: *May* 1883.

NOTE.—*Wages in the Weaving Branch of the Cotton Trade.* The president of the Manchester Chamber of Commerce (Mr. G. Lord), in response to the desire expressed by the delegates of the weaving branch at their meeting at Ashton-under-Lyne, has forwarded us the following as the data on which he based his statement to the chamber on Thursday last. The figures, as he explained, show the wages earned per week of 60 hours up to 1874, and of $56\frac{1}{2}$ hours since:—

Mill A	1850	1860	1870	1877	1883
Weavers .	9*s.* $6\frac{1}{2}$*d.*	15*s.* 1*d.*	13*s.* 10*d.*	18*s.* 6*d.*	16*s.* 0*d.*
Winders .	8*s.* 3*d.*	10*s.* 9*d.*	11*s.* 0*d.*	17*s.* 0*d.*	12*s.* 0*d.*

Increase: Weavers alone in 1883 on 1850, $67\frac{1}{2}$ per cent.; winders, $45\frac{1}{2}$ per cent.; weavers and winders together, $57\frac{1}{2}$ per cent.

This is a large mill, and the weavers' earnings per week are arrived at by taking the total earnings of the shed, and dividing that sum by the number of weavers employed. The reduction in earnings of weavers in 1870 was due to the fact that the material used at that time was not so good as that in use immediately before and since.

Mill B	1850	1860	1870	1877	1883
Weavers .	8*s.* 2*d.*	14*s.* 9*d.*	15*s.* 6*d.*	16*s.* 0*d.*	15*s.* 0*d.*
Winders .	8*s.* 6*d.*	9*s.* 0*d.*	11*s.* 6*d.*	14*s.* 0*d.*	12*s.* 6*d.*

Increase in 1883 on 1850: Weavers, $83\frac{1}{2}$ per cent.; winders, 47 per cent.; weavers and winders together, 65 per cent.

Mill C.—In 1850 a weaver received 10*s.* 4*d.* per week for attending to one pair of looms; now she receives 23*s.* for two pairs of looms, out of which she pays a tenter 5*s.* 3*d.*, leaving her 17*s.* 9*d.* Taking weavers and winders together the increase shown at this mill is $56\frac{1}{4}$ per cent.

Mill D.—In 1850 a weaver received 8*s.* for attending to one pair of looms; now she receives 24*s.* for attending to two pairs, and pays 6*s.* to a tenter, leaving her 18*s.* Taking weavers and winders together the increase shown at this mill is $84\frac{3}{4}$ per cent.

Mill E.—In 1850 a weaver earned 9*s.* $2\frac{1}{4}$*d.*; in 1883, 15*s.* $0\frac{1}{2}$*d.* Increase, $63\frac{1}{2}$ per cent.

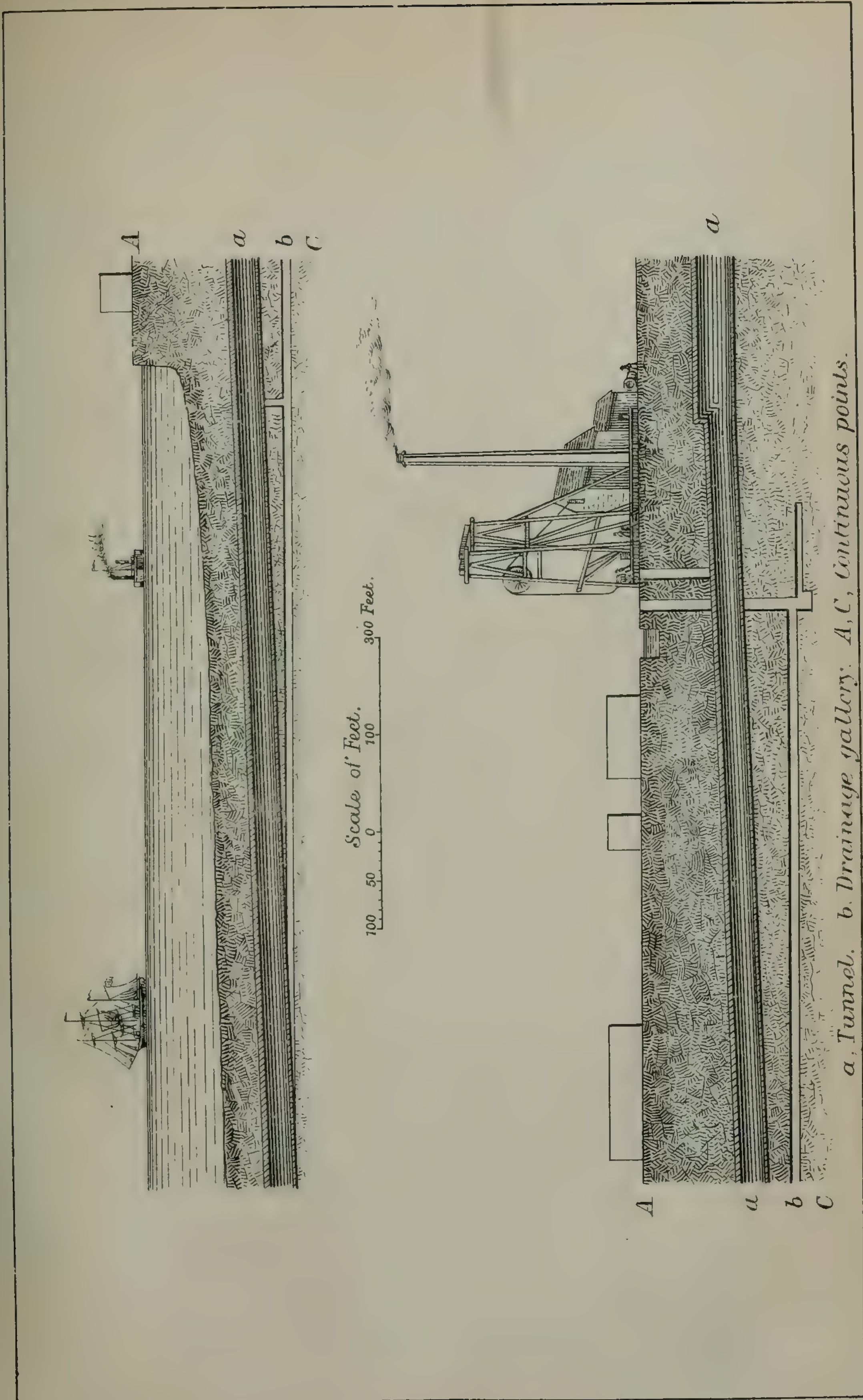
Mr. Lord states that he has a number of other returns corroborative of those above given, but he thinks it unnecessary to multiply proofs of facts so universally known to all in the trade.

On the Mersey Tunnel.
By CHARLES DOUGLAS FOX, *M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

[PLATE XII.]

AMONGST the proposals which have from time to time occupied the attention of engineers and capitalists, the bridging and tunnelling of rivers and estuaries, in order to establish direct communication between important towns or districts, have of late years occupied a prominent place, and, if practical results have only in one or two instances been attained, this cannot be attributed to any want of belief in the value of such connections, but rather to the inherent difficulties and costliness of the necessary works. The towns of Liverpool and Birkenhead, having together a population of some 750,000 persons, bound by the closest ties

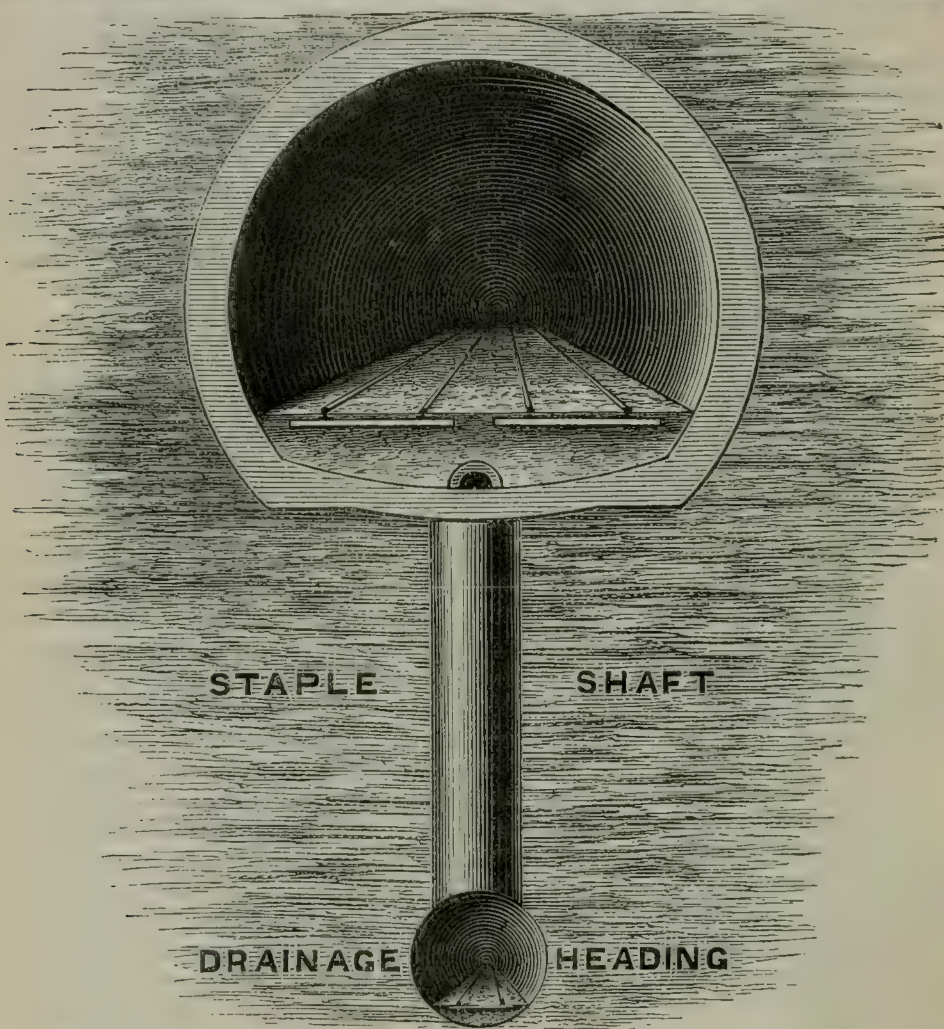


Spottiswoode & Co. Lith. London

Illustrating Mr. Douglas Fox's Paper on the Mersey Tunnel

of commercial interest, and possessing the finest docks and harbours in the world, still remain separated by the river Mersey, a deep tidal stream, some 1,300 yards in width, the interchange of traffic, amounting annually to about 26,000,000 of passengers and 750,000 tons of goods, being effected by means of steam ferries only. As long ago as 1865 it was felt that this condition of affairs seriously interfered with trade, and several proposals were put forward with a view to meeting the difficulty. A high-level bridge, and a railway tunnel crossing under the Mersey some distance above the towns, were alike considered and set aside, but, in the year 1866, the Mersey Railway Company was incorporated, with power to construct a pneumatic railway from Woodside, in Birkenhead, to Church Street, in Liverpool. By a further Act in 1871 the pneumatic system was laid aside and an ordinary railway authorised, the powers being also extended from Woodside to a junction with the joint railway belonging to the London and North-Western and the Great Western Railway Companies at Green Lane, in Tranmere. In the year 1882 the point of junction was altered, and powers taken to extend in Liverpool from Church Street to Waterloo Place, in immediate contiguity with the Central station of the Cheshire Lines Committee, and, by an Act of the present session, further capital powers were granted to the Company. It was not until December 1879 that it was found possible practically to begin operations; and, although the sinking of the shafts and driving of the heading hereinafter described was then commenced, the organisation of the company upon its present basis, with the Right Hon. Cecil Raikes, M.P., as chairman, the Right Hon. Edward Pleydell Bouverie, F.R.S., as deputy chairman, and Messrs. Boutcher, Hubbard, Mott, and Cavendish Taylor as directors, Major Isaac and John Waddell as contractors, Mr. James Brunlees and the author as engineers, and Mr. Archibald H. Irvine as resident engineer, was only effected in July 1881, since which time the works have been vigorously prosecuted. The authorised railway is 3 miles $8\frac{1}{4}$ chains in length, and will extend as a double line of railway from the junction with the joint railways at Tranmere to a terminal station in Waterloo Place, Liverpool, adjoining the Central station, with intermediate stations at Green Lane, Borough Road, and Hamilton Square, in Birkenhead, and at James Street, in Liverpool. Operations were commenced by sinking shafts on each side of the river, and just one mile apart, to such a depth, viz., about 180 feet below the level of the quay, as was necessary to ensure the efficient drainage of the lowest part of the tunnel. These shafts were both originally intended to be 15 feet in diameter when lined, but the Birkenhead shaft has been increased to 17 feet 6 inches in diameter. The Liverpool shaft passes for a short distance through made ground, and then through the red sandstone of the district, which at this point yields a considerable quantity of brackish water. At the bottom there is a pumping sump of 12 feet in depth, and a standage heading 33 yards in length, to form a safety reservoir in case of any sudden accumulation of water in the workings. It has been found necessary to tub this shaft and the standage heading with cast-iron tubbing, which involved some difficult fitting where the shaft widens out for the clack and bucket doors of the pumps. The Birkenhead shaft, also provided with a sump and standage heading, passes through the solid sandstone rock, which only yields any considerable quantity of water for a short distance, which has been tubbed against wedging cribs, the remainder of the shaft being unlined. The shafts could not be placed upon the centre

line of the tunnel, no land being available, and each is therefore connected with the drainage heading by a cross cut forming at Liverpool nearly a right angle (97 deg.), and at Birkenhead an obtuse angle (133 deg.), with the heading itself. The centre line of the tunnel having been ranged across the river by means of a transit instrument, and permanently marked on either shore, the angles and lengths of the cross-cuts were carefully measured and the work transferred to below ground by means of plumb-lines hung in the pumping shafts. These shafts were so crowded that base-lines of 12 feet only could be obtained. The lines



consisted of fine hard-drawn German silver wire, $\frac{1}{40}$ in. in diameter. This was selected on account of its tensile strength, combined with freedom from corrosion by water. There was a slow-motion screw at the point of suspension for adjusting the wires laterally, and thereby bringing them into exact position. The bobs at the ends of the plumb-lines were 33 lbs. in weight, and were hung in buckets of water to steady them. The setting out by this method was checked twice over, with but very little variation, and it is anticipated that the lines will meet very closely. In the Birkenhead shaft, where there were many obstacles, and where it

was therefore difficult to see whether the lines were hanging free, they were tested electrically. A galvanometer and battery being included in circuit with the lines, the bobs hanging free in the air, one pole of the battery was put to earth, the other being connected with the plumb-line. If making earth by contact at any point the galvanometer was deflected, the wet condition of the shaft ensuring the making of good earth. If free there was no current shown. From each shaft is being driven a heading or drainage gallery, rising with gradients of 1 in 500 and 1 in 900 towards the middle of the river, and connected, at intervals, with the main tunnel by bore-holes. The portion of this heading which is executed by hand is taken out 10 feet 4 inches in diameter, and lined with brickwork in cement 14 inches thick, thus leaving a net diameter of 8 feet. Below the invert, and for the purpose of clearing the water from the brickwork during construction, a pipe-trench is cut in the rock to receive pipes 18 inches in diameter. An attempt has been made, with some success, to stop back a portion of the water by iron cribs and brickwork in the drainage headings. Cast-iron rings, of hollow box section, being some 18 inches on the bed and 6 inches deep, have been placed at intervals, one at each end of a section of brick lining, the rock being cut out sufficiently large in diameter to receive them. The ring or crib being placed in position, and standing vertical, was tightly wedged all round the outside edge between the crib and the rock with wood wedging, until this became so compact that a chisel would not enter it. The brickwork lining between the two cribs was then completed, and the whole made tight. The intention was then to seal up the two ends, and confine the water to that particular section, and so prevent its passage along between the brickwork and the rock on to the next section. Were the rock thoroughly impervious, the result would be perfect, but, in the case under notice, a considerable proportion of the water penetrated through the rock at the back of the cribs. Instead of using cribs, close building in brick is now being resorted to, the rock having been first carefully trimmed all round. If carefully done, this baffles the water to a large extent, and is far less costly than the method above described. The pipe-trench is made good with concrete put in place in bags before setting, and the invert is constructed with blocks of brickwork prepared on the surface. Altogether 930 lineal yards of this heading have been driven by hand, the average speed at each face being 11 yards per week. The cement was at first mixed in the proportions of three to one, but, upon testing the work with the head of water, it was not found to be thoroughly watertight, and the proportion has since been increased to two to one, with the most satisfactory results. The greatest care is taken to fill any cavities at the back of the brickwork with sandstone or broken bricks in cement of the same proportion. In the spring of the present year arrangements were matured for introducing into the Birkenhead heading the machine invented by Colonel Beaumont, R.E., and Captain English, R.E., which consists of a strong frame some 30 feet long, upon which is fixed an upper bed which carries the machinery. This upper bed can be moved forward by a screw-feed on the lower frame, the feed in the sandstone rock being $\frac{3}{8}$ inch per revolution, and the speed of the bore-head about one and a half revolution per minute, being about one-third the speed at which it can be driven in chalk. When some 4 feet 6 inches have been cut the action of the feed is reversed, and, the weight of the machine being taken by hydraulic jacks, the lower frame is moved

forward ready to recommence operations. The radial arms of the bore-head are fitted with cutters, or discs of chilled cast iron, which are truncated cones, and which, as they wear, can be slightly turned round, thus exposing a fresh cutting edge without so frequently incurring the delay of replacing the cutters. The bore-head is driven by a pair of compressed air engines, having cylinders 12 inches in diameter and 18 inches stroke, and running at from 80 to 100 revolutions per minute. The compressed air is supplied at a pressure of 35 to 40 lbs. per square inch by compressors at the surface, driven by portable engines. This machinery cuts the sandstone rock cleanly and accurately to a diameter of 7 feet, delivering in small pieces. The greatest progress hitherto made has been about five yards in twenty-four hours, and twenty-four lineal yards in a week of six working days, and the machine has now driven a total of 260 yards of heading. The rock thus cut is found to yield much less water than when explosives are used, so that it has not been necessary to line this portion of the heading. Only seven men are required to work and tend the machine, which is fitted with an endless strap and buckets to deliver the *débris* into tubs at the tail. The chief difficulties encountered have been the keeping of the machine in true line and level, the dust caused in the drier parts of the rock, and the foggy atmosphere resulting from the use of compressed air, together with certain defects in detail, which are gradually being remedied. Simultaneously with the drainage headings the main tunnel has been driven forward. The excavation has been throughout in sandstone rock, the roof being generally excellent, and requiring but little support. The rock is very solid and homogeneous, but varies considerably in the quantity of water it yields, thin layers of a white colour being more porous than the rest. The rock under the river on the Liverpool side is remarkably dry. The faces under the river are carried forward by means of a bottom heading, which is first driven by hand in the usual manner, and from this 'break-ups' are made to the full size of the tunnel—not more than 12 feet lineal of excavation are allowed to be exposed at one time, the brickwork following on as closely as possible. The excavation under the river is $30\frac{1}{2}$ feet wide by $27\frac{1}{2}$ feet high, and is lined with brickwork in cement 2 feet 3 inches thick; the internal finished dimensions of the tunnel are 26 feet wide and 23 feet high, recesses for platelayers being placed at intervals. The two inner rings of brick are of Staffordshire blue, the remaining rings of Burnley or other approved red brick, the filling of broken stone or bricks, the whole set in cement, mixed in the proportion of one of cement to two of sharp sand or gravel. Landwards the lining of the tunnel is reduced in thickness to 1 foot 6 inches, and then to 1 foot 2 inches. In order to leave the main shafts clear for pumping purposes the drainage heading is now connected with the main tunnel on the Liverpool side by a staple shaft 9 feet in diameter and 25 feet deep, and a similar connection is being made on the Birkenhead side. The underground stations at James Street, Liverpool, and Hamilton Square, Birkenhead, are excavated in the solid rock, which is then lined with brickwork, and are 400 feet long and 50 feet wide by 30 feet high from the rails. These will be lighted by electricity and approached by hydraulic lifts. For the purpose of keeping the works clear of water, extensive pumping plant has been erected at Woodside, Birkenhead, and St. George's Dock, Liverpool, and this has proved most efficient. Owing to the depth of water (90 feet) in the river Mersey, and the high levels of the towns on either side,

gradients of 1 in 30 are necessary in order to provide a sufficient distance (the average thickness being 40 feet, and the minimum 33 feet) between the bed of the river and the crown of the tunnel. There are four pumping engines, two on the Liverpool and two on the Birkenhead side, of the horizontal type known as compound differential, invented by Mr. Henry Davey, and constructed by Messrs. Hathorn, Davey, and Co., of Leeds. At Liverpool the large engine is capable of raising 288,000 gallons per hour, and the other 96,000 gallons, whilst at Birkenhead the large engine will raise 234,000 gallons, and the small one 96,000, making a total from both sides of 17,136,000 gallons per day. The largest quantity of water met with has been at Birkenhead, 180,000 gallons, and at Liverpool 210,000 gallons per hour.

The dimensions of these engines, and of the pumps connected with them, are given in the following table:—

Engine	Diameter of high-pressure cylinder	Diameter of low-pressure cylinder	Stroke of engine	Diameter of pumps	Stroke of pumps
	in.	in.	ft.	in.	ft.
Liverpool . .	33	60	10	30	10
	20	35	6	20	5
Birkenhead . .	33	60	10	30	8
	20	35	6	20	5

The chief peculiarity of the differential engine is that it is capable of working with a high grade of expansion, without the controlling action of a crank or fly-wheel. The water-column and spear-rods constitute a reciprocating mass performing the function of a fly-wheel, and enabling an eight- or a ten-fold expansion to be employed. An analysis of the function of the reciprocating mass appears in the abstract of a paper by Mr. Davey, read at the Swansea meeting, and printed in the Report of this Association. The term 'differential' is applied to the engine, because of its peculiar valve-gearing, in which the engine-motion is communicated to its own steam-valves through the medium of a 'floating' lever, having no fixed fulcrum, but made to move by independent mechanism in the direction required for opening the valves, whilst the engine-motion is imparted to the same lever in the direction for closing them. The resultant of the two antagonistic motions is that actually imparted. The independent motion is adjustable, and is rendered uniform, so that any increase in the velocity of the engine-motion causes the valves to close earlier than they otherwise would. There is, therefore, a peculiar element of safety in this engine. On three occasions the engine has suddenly lost its load, and on two of these the valve-gear has saved the machinery from injury by interposing a cushion of steam, although the force has been sufficient to shift the engine-bed $\frac{3}{4}$ inch on its pillar, and to drive the packing out of the steam-pipe joints. There has only been one serious breakdown. This occurred at Liverpool on the evening of March 17 last. The load was suddenly lost with the No. 1 pump, through the fracture of the bolts in the top length of the spear. The piston returned with great force into the cylinder, thereby breaking the cover between the high- and low-pressure cylinders. The valve in this case failed to save the engine, probably on account of the fracture occurring near the end of the stroke, and so high up in the spear,

the two lifts being coupled together. When the break occurred in the No. 1 lift, the weight of the No. 2 lift was acting with the steam, and helped to aggravate matters; but the accident was chiefly due to the fact that a careless workman had left a nut projecting on the piston, which, instead of having the usual clearance, actually came in contact with the cylinder-cover, and consequently fractured it. The engines are connected with the spears of the pumps by quadrants, which were constructed by the Sandycroft Engine Works Company. The dimensions of those on the Liverpool were somewhat larger than those on the Birkenhead side, owing to the longer stroke of pumps, viz., 10 feet on that side, but in all other respects their construction is identical. The checks or sides are made of 1-inch plate iron, thickened up at the ends and centre where the pins passed through by additional pieces of plate iron. These checks are stayed to the case of the king-posts with strong latticing, and in the horizontal portion or levers with stout cast-iron distance-stays, through which pass $1\frac{1}{4}$-inch bolts. The end pins, to which the main links of the engine and pumps are attached, are 7 inches in diameter, and the centre shaft or gudgeon 11 inches in diameter. The length of the king-post, from centre-shaft to engine-pin, is 15 feet, and from centre-shaft to pumping-pin 15 feet for the Liverpool and 12 feet for the Birkenhead quadrants. The diagonal stays or tension-rods are 3 inches at the ends and 4 inches in the middle, and are provided with straps, gibs, and cotters similar to an engine connecting-rod. This construction enables the rods to be cottered up very securely, and avoids the play or looseness often observed when the diagonals have plain eyes. The weight of each pair of the quadrants, with all the fittings in connection with them, is about 22 tons. The pumps are ordinary bucket-lift pumps, with spears in the rising main. The chief difficulty has been the necessity of frequent renewal of buckets, owing to the water being full of sand. To provide duplicate power, and to prevent any possible interruption of the works during repairs to the existing machinery, an additional engine and pump is being fixed on each side of the river; and as these are of large size, a detailed description of them may not be without interest. The pumping engine is of the overhanging-beam class, patented by Mr. Barclay on August 30, 1861, which was adopted because it does not absorb much ground-space, and also on account of the small liability to accident which it possesses. It is of the compound type, having a high- and low-pressure cylinder, firmly bedded to the foundation. The high-pressure cylinder has a diameter of 36 inches, and the low-pressure cylinder 55 inches, the length of their strokes being 10 feet 6 inches and 13 feet respectively, both cylinders being double-acting. The balance-beam of the engine is placed between the foundation-walls. This beam is 19 feet long from rocking centre to centre at pump-rods, and 24 feet 6 inches long from rocking centre to end, the back end being furnished with a box having sufficient capacity to hold twenty tons of balance-weights; its depth is 4·6, and it is composed of plates of steel $1\frac{1}{4}$ inch thick, securely bound with distance-pieces of cast iron. The main beam of the engine is formed of two plates, each 32 feet 6 inches between the extreme centres. The vibrating columns are at the back end of the engine. There are two sets of parallel motion turned and polished bright, one set being required to keep the low-pressure cylinder-rod travelling parallel, and the other for the high-pressure cylinder piston-rod. There is a large connecting rod 38 feet 9 inches long between the centres for joining the point of

main beam to point of balance-beam. This rod is composed of oak, with malleable iron straps, and firmly bolted along its whole length; it is fitted with brass bushes, gibs, and cotters at each end. At each side of this rod there is a malleable iron rod, extending from main beam to a cast-iron crosshead. This crosshead is placed below the point of balance-beam, and to it the pump-rods are attached. This arrangement brings the pump-rods direct on to the main beam, on which there is but 1⅝ inch of lateral motion, thus avoiding the large swing at the point of balance-beam, and keeping the rods travelling upwards and downwards almost in a direct line, a matter of great importance in pumping machinery like the present, having a stroke of 15 feet. The pump-rods are made of wood, having four malleable iron plates at each joint. The rods are bolted to malleable iron forks, having tapered ends turned and fitted—one to the cast-iron crosshead at top end, and one to the plunger at bottom end, both held in position by a collar. The plunger pump is of the ordinary kind, having a stroke of 15 feet. The plunger is 40 inches in diameter, and turned true throughout its entire length, fitted with two malleable iron hoops at top end. The suction and delivery valves are of brass, mounted with strong steel lids having leather faces, also malleable iron guards, and fishing tackle. The rising main is of sufficient size to allow both valves to be drawn up from the surface, thereby avoiding much trouble and inconvenience during repairs; the working barrel is bored its entire length slightly larger than the plunger; the clack seats are provided with openings, 4 feet 6 inches and 3 feet 9 inches, to allow of easy access to the valves; the doors for these openings are of steel. The whole pump is set on two massive cast-iron girders, the suction-pipe passing up between them; these girders at each end rest on oak, which is bedded to a cast-iron sole-plate, resting on concrete set in strong cast-iron boxes, which are continually in the water. The weight of engine and pumps is 262 tons. The boilers, eleven in number, have been manufactured by Messrs. Daniel Adamson and Co. They are of the Lancashire type, being 28 feet long and 7 feet 6 inches diameter, each boiler having two flues 3 feet diameter, and each flue crossed by five conical circulating pipes. They are built for a daily working pressure of 70 lbs. per square inch, and are steel shell boilers, having all the rivet-holes drilled after the plates are bent into position—that is, into the form they take in the boilers—thus ensuring a perfectly true and parallel hole for the rivet. The edges of the plates are planed; the flues are solid welded in the longitudinal seams; the conical circulating pipes are solid welded into the flue-rings, and the circular joints of flue-rings made with Adamson's anticollapsive flange-seam. Thus no rivets or edges of plates are exposed to the action of the flame. The edges of the flange-seam are turned up by machinery. The boilers are riveted up throughout by special riveting machines. The shells are double-riveted in the longitudinal seams, and cross-jointed, the circular seams of shells being double-riveted. The back ends of the boilers are flanged and riveted to the shells, and the front ends are riveted to outside angle steel rings. The boilers are properly and strongly stayed with gusset as well as longitudinal bolt-stays, and fitted with round and oval manholes, and full complement of mountings and fittings to each boiler, the safety-valves to each boiler being two—viz., dead-weight valve and high-steam and low-water valves. Messrs. Adamson and Co. have made over two thousand steel boilers, and have them working, dating from twenty years old, with the most satisfactory results. This success

is no doubt greatly due to the fact that Messrs. Adamson and Co. make it a rule to test strips from every plate put into the boilers, having special machines of their own design for testing the tensile strength of the plates. The tunnel is lighted during construction by electric arc lights. The ventilation is at present secured by air-compressors, by bratticing, and by the staple-shafts connecting the tunnel and heading, but it is intended to erect permanent machinery for the mechanical ventilation of the tunnel, through which trains will run at intervals of a few minutes only. [*Note.*—The headings were successfully connected January 17, 1884.]

On Manganese Bronze.
By P. M. PARSONS, *M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

BEFORE entering on the immediate subject of this paper, I propose to give a brief description of what has previously been done in the same direction, and to review the theoretical considerations which have led to the production of manganese bronze.

Many samples of bronze made by the ancients have been found to contain a small percentage of iron, but, as far as I am aware, no traces of manganese have ever been discovered; it is not unlikely that the ancients knew that the addition of iron to bronze would increase its hardness, and introduced it with that view. In more recent times the combination of iron with the brass alloys seems to have engaged the attention of inventors considerably, and a few have also introduced manganese by reducing the black oxide of manganese and combining it with the copper, but none of these alloys appear to have shown sufficient advantages to lead to their permanent adoption.

Among the earliest of these inventors was James Kier, who, as far back as the year 1779, proposed an alloy of ten parts of iron with 100 of copper and 75 of zinc. Alloys of a similar character to this, but containing less iron and different proportions of copper and zinc, were subsequently introduced under the name of stereo-metal and aitch-metal, and Sir John Anderson, late Superintendent of the Royal Gun Factories, and Inspector of Machinery to the War Department, carried out a number of experiments with similar alloys, and with some good results, but no practical applications of any of them appear to have been made. The addition of iron unquestionably increased the strength and hardness of these alloys, but the experiments I have made show that they acquire these qualities at the expense of ductility and toughness, and it is probably on this account that they have not come into general use. Besides these, various other inventors have proposed to combine iron with the brass alloys, but only Mr. Alexander Parkes, and the late Mr. J. D. Morries Stirling, both eminent metallurgists, proposed the use of manganese and appear to have carried their ideas into practice.

Mr. Parkes's inventions consisted in combining manganese with copper, and using this alloy instead of ordinary copper with zinc, to form improved alloys of brass, yellow metal, &c., of which to make sheathing, rods, wire, nails, tubes, &c. Mr. Everitt, of Birmingham, has also lately

brought forward an alloy made in a similar manner. No comparative experiments as to the strength, hardness, or ductility, or other qualities of these alloys, have come under my notice; but I believe the only effect of the manganese alone that I can discover is to add somewhat to the toughness and ductility of the alloys, and allow copper and zinc of a somewhat inferior quality to be used in the manufacture of brass and other similar alloys, which, without the manganese, would not stand the working necessary to shape them into the various articles for which they were destined.

Mr. Morries Stirling, in 1848, however, proposed to use manganese in various brass alloys in which iron was present, but in a very different manner from that employed by me. Mr. Stirling first combined about 7 per cent. or less of iron, with the zinc, and added to the copper a small percentage of manganese by reducing the black oxide of manganese with the copper, in the presence of carbonaceous materials, and then added to it the requisite quantity of the iron and zinc alloy to make the improved brass required. Mr. Stirling described a method of combining the iron with the zinc by fusion, but in practice he found a more ready means of procuring the zinc and iron alloy by employing the deposit found at the bottom of the tanks used for containing the melted zinc for galvanising iron articles; this product consists of zinc with from 4 to 6 per cent. of iron, but this percentage is very variable, and this material is useless if the amount of iron is required to be adjusted with accuracy. Another great drawback to this class of alloy is the great difficulty of producing sound castings of them in sand moulds with any certainty.

These, then, were the chief inventions that have come under my notice at all approaching mine in character, or similarity, at the time I introduced it, which invention I now proceed to describe.

The manganese bronze is prepared by introducing and mixing with the copper, to be afterwards made into alloys similar to gun-metal, bronze, brass, or any other alloy, of which copper forms the base, a small proportion of ferro-manganese. The ferro-manganese is melted in a separate crucible, and is added to the copper when in a melted state, and at a sufficiently high temperature.

The effect of this combination is similar to that produced by the addition of ferro-manganese to the decarburised iron in a Bessemer converter; the manganese in a metallic state, having a great affinity for oxygen, cleanses the copper of any oxides it may contain, by combining with them and rising to the surface in the form of slag, which renders the metal dense and homogeneous. A portion of the manganese is utilised in this manner, and the remainder, with the iron, becomes permanently combined with the copper, and plays an important part in improving and modifying the quality of the bronze and brass alloys, afterwards prepared from the copper thus treated; the effect being greatly to increase their strength, hardness, and toughness; the degrees of all of which can be modified at will, according to the quantity of the ferro-manganese used, and the proportions of the iron and manganese it contains. By these variations, together with variations in the proportions of copper, tin, and zinc employed, a most valuable group of new alloys has been produced, possessing qualities in the way of strength, hardness, toughness, &c., far beyond anything yet obtained in any similar alloys.

It will be seen that the process described of making the manganese bronze is altogether different, both in principle and effect, from Stirling's

or Parkes' inventions. By Stirling's method, combining the iron with the zinc, in order to introduce it into the alloys, altogether precludes its use in any but those alloys in which a considerable portion of zinc is employed, such as brass or yellow metal. It could not be applied to any of those important alloys, of the nature of gun-metal or bronze, in which copper and tin are the chief ingredients, and which form some of the most valuable qualities of the manganese bronze; but an equally important difference in the manufacture of manganese bronze consists in adding the manganese in its metallic state, in the form of ferro-manganese, to the copper, by which the copper is cleansed from oxides as before explained, which cannot be the case when the manganese is reduced from the black oxide and combined with the copper, by one and the same operation, in the manner pursued by Parkes and Stirling.

Another point of great importance is the very great nicety with which both the iron and manganese can be adjusted, and the effect controlled by adding the ferro-manganese to the copper, as pursued in the manufacture of manganese bronze. The amount of manganese required for de-oxidising the copper and for permanent combination with it, having been ascertained by experience, it is found that very slight variations in quantity have a perceptible and ascertained effect in modifying the qualities of the alloys produced; that is to say, the toughness can be increased and the hardness diminished, or *vice versâ*, at will, precisely as is done in the manufacture of steel, by increasing or diminishing the dose of carbon and manganese.

In preparing the ferro-manganese for use, that which is rich in manganese, containing say from 50 to 60 per cent., is preferred; this is melted with a certain proportion of the best wrought-iron scrap, so as to bring down the manganese to the various proportions required. At the same time any silicon it contains is reduced and the metal refined. About four qualities are made in practice, containing from about 10 to 40 per cent. of metallic manganese. The lower qualities are used for those copper alloys in which the zinc exceeds the tin, and the higher qualities in which tin is used alone, or exceeds the zinc used in combination; and the amount of ferro-manganese added varies generally from about 2 to 4 per cent.

After a number of experiments and tests, the Manganese Bronze and Brass Company, who are the sole manufacturers, have adopted the manufacture of five different qualities of manganese bronze, although other varieties can be produced for special purposes. The distinctive features, peculiarities, and purposes for which these qualities are suited are as follows:—

No. 1. In this quality the zinc alloyed with the copper is considerably in excess of the tin. It is cast into ingots in metal moulds, and then forged, rolled, or worked hot, and made into rods, plates, sheets, sheathing; and it may also be worked cold, and drawn into tubes, wire, &c. When simply cast, it has a tensile strength of about twenty-four tons per square inch, with an elastic limit of from fourteen to fifteen tons. When rolled into rods or plates, it has a tensile strength of from twenty-eight to thirty-two tons, with an elastic limit of twelve to twenty-three tons per square inch, and it stretches from 20 to 45 per cent. of its length before breaking. When cold rolled, the elastic limit rises to over thirty tons, and the breaking strength to about forty tons, and it still elongates about 12 per cent. before breaking.

No. 2 is similar to No. 1, but still stronger, and it can with the required care be cast in sand, when it is required to produce castings for special purposes, possessing the greatest strength, hardness, and toughness, but it must be melted in crucibles; passing it through the reverberatory furnace injures the metal, and causes unsound castings. It is not, therefore, adapted for general brassfounders' purposes, and those only who understand its peculiarities and are experienced in its use should attempt casting it in sand. One of the most important applications of this quality is that of producing articles cast in metal moulds under pressure. Blocks of this metal thus simply cast have all the characteristics of forged steel, as regards strength, toughness, and hardness, without any of its defects. It is perfectly homogeneous, and, while not possessing a fibrous texture, derived from rolling or hammering, it is still fibrous in character, and this in not one but in all directions alike, and when broken shows a silky fracture. Its tensile strength is from thirty to thirty-five tons per square inch, its elastic limit from sixteen to twenty-two tons, with an ultimate elongation of from 12 to 22 per cent. It can be cast on to any object, and will shrink on to it with a force equal to its elastic limit, and when released will show an amount of resilience about double that of steel. Thus a hoop shrunk on to a solid cylinder of iron gave the following results:—It stretched when hot ·03 of its diameter in the process of contraction, and when cold and relaxed sprang back about ·003 of its diameter. As regards hardness, it is about equal to mild steel. To compare it with gun-metal, wrought iron, and steel in this respect, the following tests were made, by forcing a knife-edged angular die into the flat surfaces of each of these metals. To make a dent of equal length, the following pressures were recorded:—

Gun-metal	12 cwts.
Wrought iron	15 ,,
Mild steel	20 ,,
Mild steel, oil hardened.	25 ,,
Manganese bronze, as cast	20 ,,
Manganese bronze as cast hardened by cold pressure	22 to 23 ,,

All these results point to this material as a most suitable one for the construction of hydraulic and other cylinders required to stand great strains, and particularly for ordnance.

The Manganese Bronze and Brass Company are now making arrangements for casting a block of this metal, to be made into a gun; and the results are being looked forward to with much interest, as, should this prove successful, the material is likely to become a formidable rival to steel and iron for the construction of artillery; for, although the metal itself is more costly, the simple way in which it can be manipulated will make the total cost less, and the time required to construct heavy guns of it will probably be less than one-fourth of that required to build up iron or steel guns.

No. 3. This is an equally important alloy with the last, but possessing altogether different qualities, and suited to different and more varied applications. It is composed principally of copper and tin in about the proportions of gun-metal, combined with a considerable dose of ferro-manganese. Its chief characteristics are very great transverse strength, toughness, and hardness, the facility with which it can be cast, and the soundness and uniformity of the castings produced, without any special

care having to be taken beyond what is ordinarily given in casting gun-metal.

It also possesses this very important advantage in the production of large castings, that it may be melted in an ordinary reverberatory furnace without injury to the metal; very careful analysis of this alloy before and after passing through the reverberatory furnace showing that there is no appreciable alteration in its constituents. A bar of this metal cast in sand in the ordinary way, 1 inch square, placed on supports 12 inches apart, requires upwards of 4,200 pounds to break it; and before breaking it will bend to about a right angle, and it will sustain from 1,700 to 1,800 lbs. before taking a permanent set. These results are in every respect fully up to those of the best rolled wrought iron, as some test bars of both, exhibited, will show: we have therefore in this a material which can be cast with facility into any intricate form, which it would not be possible to forge in iron, yet possessing all its strength, toughness, and hardness. This quality of manganese bronze is used for a variety of purposes, including spur bevel, and all kinds of toothed wheels, gearing, worms and worm wheels, framing, brackets, and all kinds of supports, and connections of machines, crank-pin brasses, the shells of main and other bearings of marine and other engines, axle-boxes and other parts of locomotive engines; and it has been found admirably adapted for statuary and art purposes generally, being much admired for its fine colour; but the latter quality is quite a matter of taste, and the members of the Association will be able to form their opinion thereon by examining the beautiful clock and ornaments, kindly lent by Messrs. Elkington & Co., made of the manganese bronze. The metal also seems to be peculiarly adapted for large bells. The advantages in this latter application are that bells cast from it possess the same, or greater, sonorousness with a more mellow tone, and are at the same time so tough that they cannot by any means be cracked, like bells made of ordinary bell-metal, which is obliged to be made brittle in order to acquire the requisite sonorousness. The sound of a bell is also, to some extent, a matter of taste, and those who take an interest in this question may form an opinion as to the suitableness of the manganese bronze for this purpose by sounding the one exhibited. But the most important application, in a commercial point of view, is undoubtedly to that of steamship propellers, to which it has been largely applied.

Owing to the great strength of this metal, and its non-liability to corrosion, propellers of it can be made thinner than even those of steel, the surface is beautifully smooth, and when cast they are theoretically true to form, as, not having to pass through the annealing furnace, they do not become distorted, as is generally the case with steel. For these reasons the manganese bronze has a great advantage over steel. It has been proved conclusively by the logs of a number of steamships that have had their steel propellers replaced by manganese bronze blades that their speed has been increased, and the consumption of coal diminished, while the weight, vibration, and strain on the ship and machinery is considerably reduced. In addition to this, all these advantages are secured at a considerably less ultimate cost, taking it upon the average life of a vessel; for although the first cost of a manganese bronze propeller, or a propeller with manganese bronze blades, is about double that of steel, it is indestructible, whereas at the end of about every three years the steel blades become so pitted and corroded that their renewal is indispensable, which

brings up the total cost of the steel blades, on an average, to two or three times that of the manganese bronze.

That the manganese bronze propellers are incorrodible, and in every other respect efficient, has now been proved by experience, as some have been at work approaching three years, and are as perfect in every respect as when first applied. Some time after the introduction of the No. 3 quality for propellers, the No. 2 was employed for some propeller blades, as fears were entertained as to the No. 3 setting up galvanic action and corroding the stern frames. Most of these propellers stood well, but some of the blades failed, and it was found on examination that the castings were unsound, owing to the metal having become deteriorated by melting in a reverberatory furnace. In consequence, it has now been determined to adhere solely to the No. 3, as this quality has always given the greatest satisfaction, both as to its facility in casting and efficiency under trial; and further experience proves the supposed galvanic action to be only a myth, or if there should be a tendency to it, it is effectually prevented by lining the inside of the stern frame with zinc strips.

A proof of the soundness and tenacity of the manganese bronze was shown in an accident, which occurred to one of the blades of the 'Garth Castle,' at its launch from the yard of Messrs. John Elder & Co., in 1880, when one of the blades came in contact with the jetty, and was bent round, without even a crack, to nearly a right-angle, and was afterwards hammered back cold to its original form without detriment. The photograph exhibited shows the blade from two points of view bent, and the other view as hammered back; another photograph shows one of the blades of the North German Lloyd's steamship 'Mosel' (kindly lent by Messrs. John Elder & Co.), recovered from the ship after she was wrecked, in which the metal was subjected to a still more severe punishment without breaking than even in the case of the 'Garth Castle.'

The other qualities, Nos. 4 and 5 of the manganese bronze, have no particular claims to strength, but are most effective for the purpose of bearings, slide valves, slide blocks, piston rings, &c., and in all situations where friction occurs, and are much more durable than ordinary gun-metal.

Before concluding I may add a few words on the art of brassfounding generally, and I cannot help saying that, as at present practised, it appears to me to be very far behind what might be expected in these days of progress.

In the manufacture of iron and steel an amount of scientific knowledge has been brought to bear which elevates these industries into scientific processes, but I can discover nothing of the kind in bronze and brassfounding as ordinarily practised; everything is done by the rule of thumb, and that in a most clumsy manner. The idea of combining the various metals to form the alloys required in atomic proportions does not seem to have been ever entertained, and even the books written for the practical guidance of brassfounders, ignore this important principle altogether.

I must not be understood as applying this remark to Dr. Percy and Mr. Mallet, and other scientific metallurgists who have drawn attention to the subject, and made valuable suggestions respecting it in their well-known works; but I allude to that class of books generally termed handbooks, and the like, which contain instructions of the most clumsy and unscientific character for making different alloys. Thus for gun-metal,

the proportions given are 1 lb. of copper to 2 oz. of tin, or if required to be harder, $2\frac{1}{4}$ oz. or $2\frac{1}{2}$ oz., and so on; then as regards brass, it may be 70 lbs. of copper and 30 lbs. of zinc, or 60 lbs. of copper and 30 lbs. of zinc, or 60 lbs. of copper and 40 lbs. of zinc for yellow metal, and so on.

Now, not one of these alloys or others described are in atomic proportions, and that is the reason why unsatisfactory results are constantly occurring in ordinary brassfounding; not only are the copper alloys thus produced weak, soft, spongy, and porous, but it is a constant occurrence that the constituents vary in different parts of the casting; this is the case principally in the gun metal and bronze alloys, the surplus tin above that forming a definite alloy in atomic proportions seems to be held in mechanical suspension, separates by liquation, and collects at the top of the casting as it cools and solidifies, causing the well-known tin spots, sponginess, &c.

The only remedy the ordinary brassfounder has for this is to use as large a proportion of scrap-metal as he can get; he does not know why, he only knows that he gets better castings by using it; but the true reason is that the scrap-metal has adjusted its constituents in atomic proportions during the several remeltings it has undergone, the surplus tin or zinc having been got rid of by liquation and oxidation; but if in the original manufacture of the alloy the metals are combined in atomic proportion, nothing of this kind happens, the castings are sound, and the alloys homogeneous and stable.

In the manufacture of manganese bronze this principle is always kept in view, and all the different qualities produced have the metal they are composed of combined in atomic proportions. Whether by this any chemical combination is effected, it is difficult to say; but this much I can vouch for, that the alloys thus produced are finer in texture, more homogeneous, stronger, and of a very much more stable character than when not so combined; thus, in the No. 3 quality the addition of $\frac{1}{4}$ per cent. of tin, instead of making it harder and stronger, as it ought to be according to the ordinary accepted ideas, actually makes it softer and weaker and the grain coarser, and the same thing occurs if the additional tin is increased $\frac{1}{2}$ or 1 per cent., until the tin arrives at another definite atomic proportion, when an alloy of a different character appears, but it then becomes again close-grained, sound, homogeneous, and stable.

As a further proof of the soundness of this theory, the No. 3 quality may be passed through an ordinary reverberatory furnace, and although in being thus treated it is exposed for a considerable time to the action of an oxidising flame, no appreciable diminution of the tin in its composition has been detected. Then again, both the No. 1 and No. 2 may be remelted several times in the crucible, if it is done with care, without any alteration of its components.

It is well known how difficult it is to melt brass and yellow metal, even in a crucible, when every precaution is taken, without some of the zinc escaping in fumes. This also, to a certain extent, occurs in melting the No. 1 and No. 2 manganese bronze; but the zinc apparently carries its atomic complement of copper with it, so that the proportions of what remains are not disturbed. I am led to this belief not only by examining the metals after remelting, but by the colour of the condensed fumes, which, instead of being white, as they are when produced from zinc alone, have a beautiful pink colour, which I can only attribute to the presence of copper.

Another, and perhaps still more palpable proof of the value of combining the metals in their atomic proportions is that, when this is done, the specific gravity of these alloys is perceptibly increased over those not so combined, even though in the latter case the heavier metal be in excess.

I was much struck by this fact in taking the specific gravity of some No. 1 manganese bronze, which contains a considerable amount of zinc, and which, judging by its constituents, ought to be a comparatively light metal; but the trial proved that it was about equal to that of ordinary gun-metal, composed of copper and tin, and very considerably above the mean weight of the metals composing it, indicating to my mind that these metals must have combined in such a manner as each to fit into, and more nearly fill up, the infinitesimal spaces between the atoms of the other, and if not actually forming what chemists would admit to be a perfect chemical combination, certainly more nearly approaching it than when the metals are mixed together in the haphazard manner usually prevailing.

I have no doubt that these combinations and the stable quality of the manganese bronze alloys is due also very materially to the action of the metallic manganese on the copper, by freeing it from the oxides it contains and bringing the metals added to it into actual contact, and thus enabling them to combine in a more perfect manner than has been accomplished hitherto. I have only now to refer to the list of tests appended, which it would be tedious to recite; but they can be referred to, and the results will be found attached to the samples, as also a description of the other articles exhibited.

Tests of Manganese Bronze.

By Tensile Strain.

Description	Where Tested	Reference Number	Elastic Limit Tons. Per sq. in.	Breaking Strain Tons. Per sq. in.	Ultimate Elongation. Per cent.	Remarks
No. 1 Quality Rolled Rods	R. G. F.	6,536	11·00	29·00	44·6	Mild for riveting cold and annealed.
	U. L. C.	5,060	13·17	29·29	33·4	Annealed.
	Do.	4,995	23·54	31·60	26·5	As delivered from the rolls hot.
	Do.	4,996	24·32	31·43	23·3	
	R. G. F.	6,547	34·40	39·60	11·6	Ditto and finished cold.
No. 1 Qlty. Rolled Plates	R. G. F.	7,365	14·06	28·46	23·2	Pulled across fibre. (Annealed.)
	Do.	7,369	14·06	30·13	47·8	„ with fibre.
	Do.	7,372	14·80	30·78	34·1	„ across fibre.
	Do.	7,374	16·70	30·10	28·8	„ with fibre.
No. 2 Qlty. cast under pressure.	M. B. & B. Co.	1	18·00	35·00	22·0	Cast in an iron cylinder and pressed while liquid.
	Do.	2	16·23	31·90	12·4	

No. 1 cut from side of ingot and No. 2 from centre.

Test of a Bar of Manganese Bronze, No. 5.

By Transverse Strain.

1 inch square, Cast in Sand, placed on supports 12 inches apart,
Steady pressure applied in middle of Bar.

Strain in Pounds	Deflection, Strain on, inches	Per Set, Strain off, inches	Strain in Pounds	Deflection, Strain on, inches	Per Set, Strain off, inches
896	·025	......	2,688	·21	·12
1,120	·03	......	3,136	·44	·34
1,344	·04	......	3,584	·86	·73
1,568	·045	......	4,032	1·62	1·44
1,792	·06	·005 } E limit	4,144	1·97	......
1,904	·065	·01 } E limit	4,256	Gave way without breaking, and bent to a right angle.	

Tests of Manganese Bronze.

By Torsion.

Description.	Where Tested	Reference Number	Diameter Ins.	Twisting Moments in Inch Pounds		Amount of twist in length of one diameter No. of Turns	Remarks
				Elastic Limit	Breaking Strain		
No. 2 cast under pressure	U. L. C.	5,023	0·622	1,170	3,360	0·183	Uniform twist.
	Do.	5,024	0·624	1,200	3,372	0·166	" "
No. 1 rolled.	Do.	5,064	·621	1,110	2,880	0·175	Annealed.
Rod	Do.	5,065	·621	1,980	3,242	0·165	Rolled hot and tested as it came from rolls.

No. 5064 was removed from machine unbroken.
" 5065 was broken, showing a clean shear.

Experiments on the Transverse Strength and Toughness of Bars of Manganese Bronze as compared with Wrought Iron and Gun-metal, made by dropping a weight on the middle of the Bar resting on supports at each end.

Weight of Monkey, 50 lbs.; Height of Fall, 5 feet; Distance between Supports, 1 foot; Dimensions of Bar, 1 inch square, 14½ inches long.

Of the gun-metal in the annexed table specimens Nos. 1, 2, and 3 were sent from the locomotive works of one of the railways terminating in London, and tested in the presence of an officer of the department, and fairly represent the qualities of gun-metal ordinarily found in such works, and supplied by brassfounders. Nos. 4 and 5 were cast specially and composed of best selected copper, 16 parts, English tin, 2 parts: No. 6, of copper, 16 parts, and tin, 2½ parts by weight.

No. of Blows	PERMANENT DEFLECTION IN INCHES, IN THE LENGTH OF 12 INCHES.											
	WROUGHT IRON		GUN-METAL						MANGANESE BRONZE			
	Stafford-shire Rolled		Cast in Sand						No. 3 Cast in Sand		No. 1 Forged	
	No. 1	No. 2	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 3	No. 4	No. 5	No. 6
1	·57	·58	·82	·86	·90	·72	·73	·46	·66	·60	·59	·60
2	1·10	1·15	1·50	1·58	1·63	1·32	1·42	and	1·20	1·15	1·06	1·08
3	1·62	1·71	1·70	2·22	2·35	1·92	1·52	broke	1·70	1·60	1·44	1·50
4	2·13	2·23	and	and	2·86	1·94	and	—	2·23	2·07	1·80	1·89
5	2·65	2·77	broke	broke	and	and	broke	—	2·67	2·52	2·12	2·26
6	3·19	3·37	—	—	broke	broke	—	—	3·11	2·97	2·45	2·65
7	3·77	3·99	—	—	—	—	—	—	3·58	3·39	2·77	2·99
8	4·39	4·63	—	—	—	—	—	—	4·02	4·04	3·05	3·38
9	not	broken	—	—	—	—	—	—	not	and	3·33	not
10			—	—	—	—	—	—	broken	broke	not	broken
11			—	—	—	—	—	—	—	half	broken	—
12			—	—	—	—	—	—	—	thro'	—	—
13			—	—	—	—	—	—	—	—	—	—

Nest Gearing.

By Professor H. C. FLEEMING JENKIN, *F.R.S., M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

[PLATES XIII., XIV., and XV.]

IN the winter of 1882, when engaged with Professors Ayrton and Perry in the development of designs for telpherage, I was shown by them the design for driving a dynamo by two rollers, shown in fig. 1. This plan has been used, I believe, in connection with blowers for some time, but I am not aware with what results. It has the merit of relieving the bearing of the dynamo from unnecessary pressure. It seemed to me that perhaps better results might follow if a belt were allowed to embrace the three pulleys, as in fig. 2, a plan which I have since learnt is adopted by Mr. Killingworth Hedges. I was, however, by no means convinced that a short tight belt in these circumstances would work well, and I was thus led to consider the possibility of including the set of pulleys inside a rigid ring. The only difficulty appeared to be how the pressure should be maintained. The idea of a rigid smooth ring enclosing a set of smooth rollers, so pressed by the ring and against each other as to bring no pressure on the spindles or shafts, was not novel, although I was at first not aware of this. Mechwart has used the principle in his rolling mills, although in this case he does not use the rollers as gear, but drives the shafts by spur-wheels. Mr. Foster, however, in 1882, took out a provisional specification in which one form of nest gear is clearly described. Fig. 3 shows a model of this gear, which has been used

by Professor Osborne Reynolds in teaching his class. We have here a central roller A, pressed on by three intermediate rollers B_1 B_2 B_3, which are all held in what I have called a nest ring D pressing the whole together. The pressure is caused and maintained by coning the rollers as shown in section. When the two halves of pulleys B are pinched together, they are wedged against D by A, and the necessary adhesion obtained, allowing D to drive A or A to drive D.[1] Mr. Foster has informed me that he considered his invention to be this mode of tightening, for that he had met with examples of similar nests in which an attempt had been made to get the pressure simply by initial fitting. Mr. Foster's mode of tightening is ingenious, and a modification of it will probably be found very useful; the surfaces of the rollers do not roll true on each other, and although the friction from this cause is less than in the old V friction gear, it is considerably greater than we shall have in true rolling nest gear. The possibility of tightening by cones and by double-cones occurred to me independently; and at about the same time Mr. Williamson, a draughtsman then employed by Messrs. Ayrton and Perry, conceived the idea of a nest which was almost identical with Mr. Foster's. My own favourite idea when I took out my first provisional specification in the spring of this year was to tighten the rollers by the means shown in fig. 4. A is placed excentrically to D; there are three rollers, B_1 B_2 B_3, of which B_1 is smaller than the two others; all the rollers have simple cylindrical surfaces which would develop as planes; the tightening is effected by forcing one of the rollers, as B_2, from a wider into a narrower part of the space between A and D. When the excentricity is not great a very moderate force on the spindle of the tightening roller will maintain a great pressure between the rollers. Mechwart, I have since found, employs a similar adjustment to vary the space between his laminating rollers, but, as I have already pointed out, he did not construct gear to be substituted for toothed wheels in any case, whereas the nests which I am describing are gear in the sense that they can be used instead of spur-wheels and pinions. Nests tightened by this excentric method are exhibited at Southport as part of a large winch made by Messrs. Stothert and Pitt. It has also been employed in a telpherage locomotive designed in the office of the Telpherage Co., and made by Messrs. Crompton. In both cases the gear works extremely well, and the rolling friction has proved to be smaller than I anticipated. I am not yet able to give accurate information as to this friction, nor as to the wear, but I can say that the friction is less than that of spur-wheels when these are transmitting considerable force, although more than that of spur-wheels when these are running quite slack. The efficiency of the winch when lifting $1\frac{1}{4}$ tons is about 80 per cent. It contains two large nests, or has, in other words, double purchase, and the speed of the chain lifting the weight is about $\frac{1}{100}$th the speed of the handles. The design of the winch is in several respects defective, the rollers B_1 B_2 B_3 are all overhung and imperfectly supported; they do not therefore lie with the axes quite parallel. This leads to two bad results. 1. There is a screwing action tending to move the rollers lengthways against the collars or flanges by which they are retained. 2. It tends to reduce the line of contact between the convex rollers to a point where the cylinders cross, and at this point wear occurs. It will be quite easy

[1] Since reading this paper I have found a patent by Mr. Tibbitts containing the same arrangements.

FIG. 1

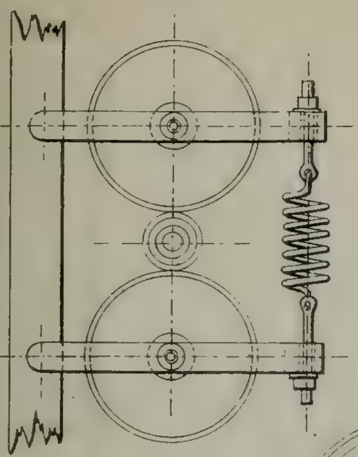


FIG. 2

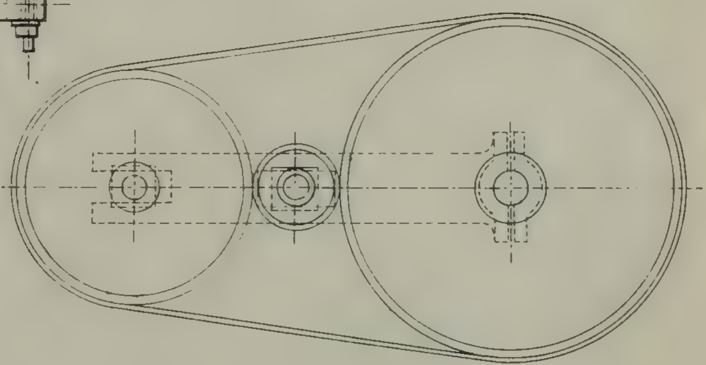


FIG. 3

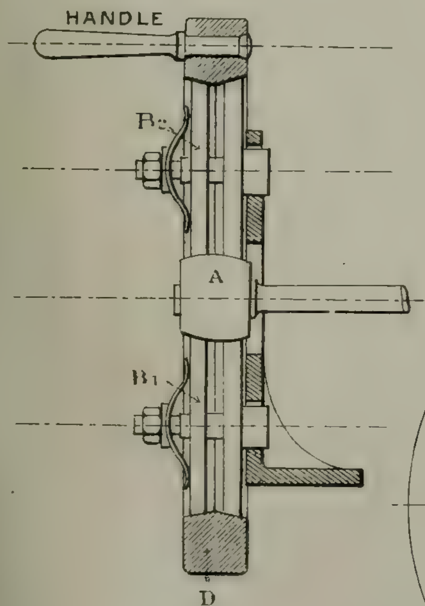
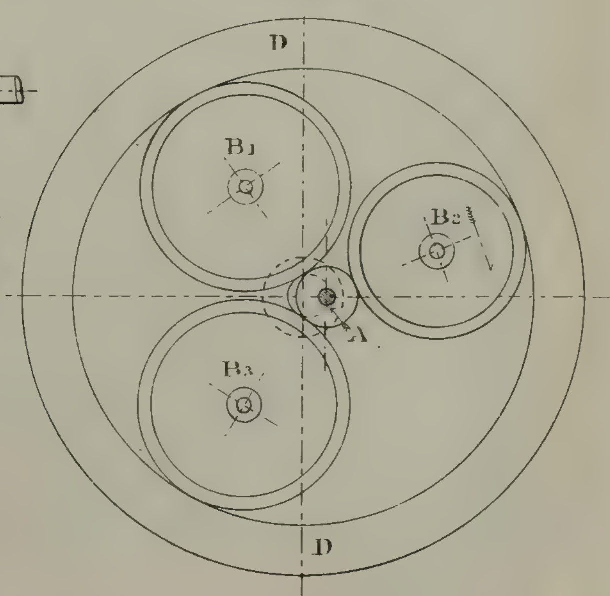


FIG. 4



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Illustrating Professor H. C. Fleeming Jenkin's Paper on Nest-Gearing

to remedy these defects in future designs. The pressure on the surfaces is such as allows one inch of breadth to transmit about 200 lbs. of force, but we do not yet know the wear under these conditions. The smallest of the rollers is 3 ins. in diameter.

I am now inclined to think that the excentric method of tightening will prove less convenient than other plans, some of which will be presently described. The framing and system of levers for the excentric method are complex, and it is found necessary (in order to avoid useless friction) to slack back the tightening screw a little after each fresh adjustment of the tightening roller. This prevents the advantageous use of a spring to take up the wear by constantly forcing the tightening roller into the narrow part. I prefer the method of tightening in which two external reverse coned surfaces are pinched between two internal coned surfaces, as in fig. 5, but when tightening is effected in this way the surfaces of the two convex rollers, as at A and B, should be flat cylindrical surfaces rolling true together.

Messrs. Ayrton and Perry have constructed a nest (not exhibited here) in which the pinching is effected by an ingenious arrangement of the outer nest ring, and in this nest the ring itself is stationary, while the nest of intermediate rollers, with their frame, revolves. These experiments have in certain cases given an apparent efficiency of 97 per cent. for this nest, multiplying the angular velocity nine times. The grinding action due to the coned surfaces is very much less than in the old forms of friction gear, and is indeed insignificant, as will be seen from a simple calculation of the difference of velocities between the mean circumference and the extreme on either side. When the breadth is say $\frac{1}{2}$ in., the taper 1 in 5, and the diameter of the two rollers in gear say 18 ins. and 8 ins. respectively, the rubbing action of the two wheels rolling together at the mean diameter will, at the extreme edge of the path, be due to a gain or loss of ·0625 in. in 18 ins., or about 0·348 per cent. Whatever be the coefficient of friction, if the pressure were only just sufficient to prevent gripping, this would entail a loss of only 0·348 per cent. in the power transmitted. It would actually be somewhat larger than this, but still insignificant where the breadth of bearing is small compared with the diameter, and where the intermediate rollers are large. I myself prefer to get the pinching by causing one or more intermediate rollers to expand lengthways. In that case only one intermediate roller need grind or bear on the cones. The two others may run on the flat surface between the cones.[1]

In fig. 6 will be seen a modification which I believe to be wholly novel. In this arrangement we have a multiplication in a duplex ratio. The two parts D and D_1 of the nest ring may be joined or they may be wholly separate. The modes of tightening may be any of those described. The gear so far described has been suited for joining shafts which have their axes in one straight line, or in parallel lines which are not far apart. I have called it concentric nest gear. I next pass to right-angled nest gear, the first form of which was due to a suggestion of my son, C. Frewen Jenkin. In its simplest form this gear is shown in fig. 7, where the contact between the surfaces of D D_1, the nest discs, with B and B, the intermediate rollers, is confined to a single point. In this figure the

[1] Since reading this paper at Southport I have patented a plan in which, by inclining the two sides of this expanding roller, all the coned surfaces run true on each other.

tightening is given by a spring acting on one disc, which slides on the shaft *d*, being prevented from turning by a feather. This form is employed for the gripping wheels of the telpherage locomotive made by Messrs. Easton and Anderson, and may be seen in the exhibition driven for a yard or two by an electric current. One development of right-angle gear, due to Messrs. Ayrton and Perry, fig. 8, is employed in the small telpherage locomotive designed by them, and now in the room. Here the contact takes place along a line; the tightening is effected by wedging, and instead of two discs joined together by a spring, we have a single wheel with a rim in which the cones run.

Figs. 9 and 10 show two further developments of right-angle nest gear contained in my first patent; the action is obvious. In addition to the forms of gear which have now been described, several applications of the principle have been made to oblique gear, to gear between parallel shafts, and to gear with belting, but the time at my disposal will hardly allow my explaining them or the latest methods of tightening. I trust to be able before the next meeting to publish results obtained from more prolonged and exhaustive experiments on various forms of the gear.

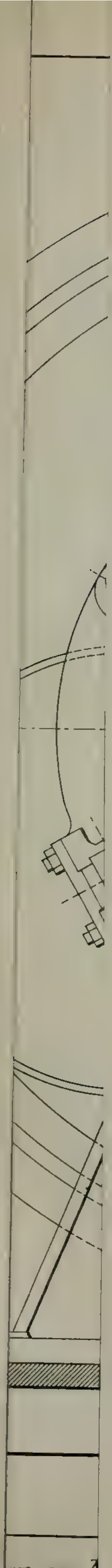

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FIG 5

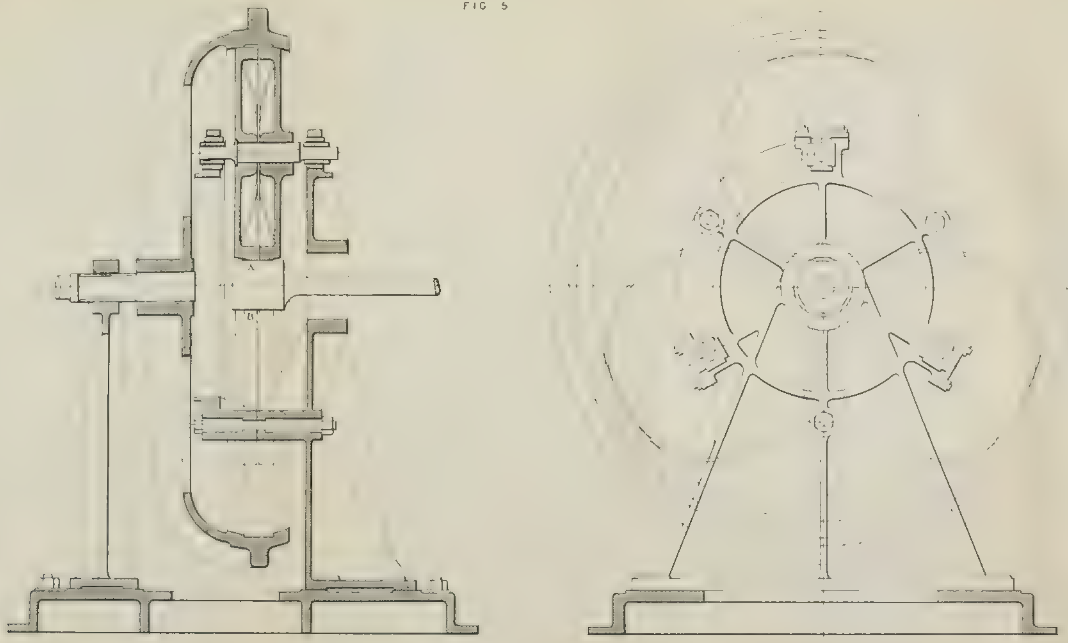

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Plate XV

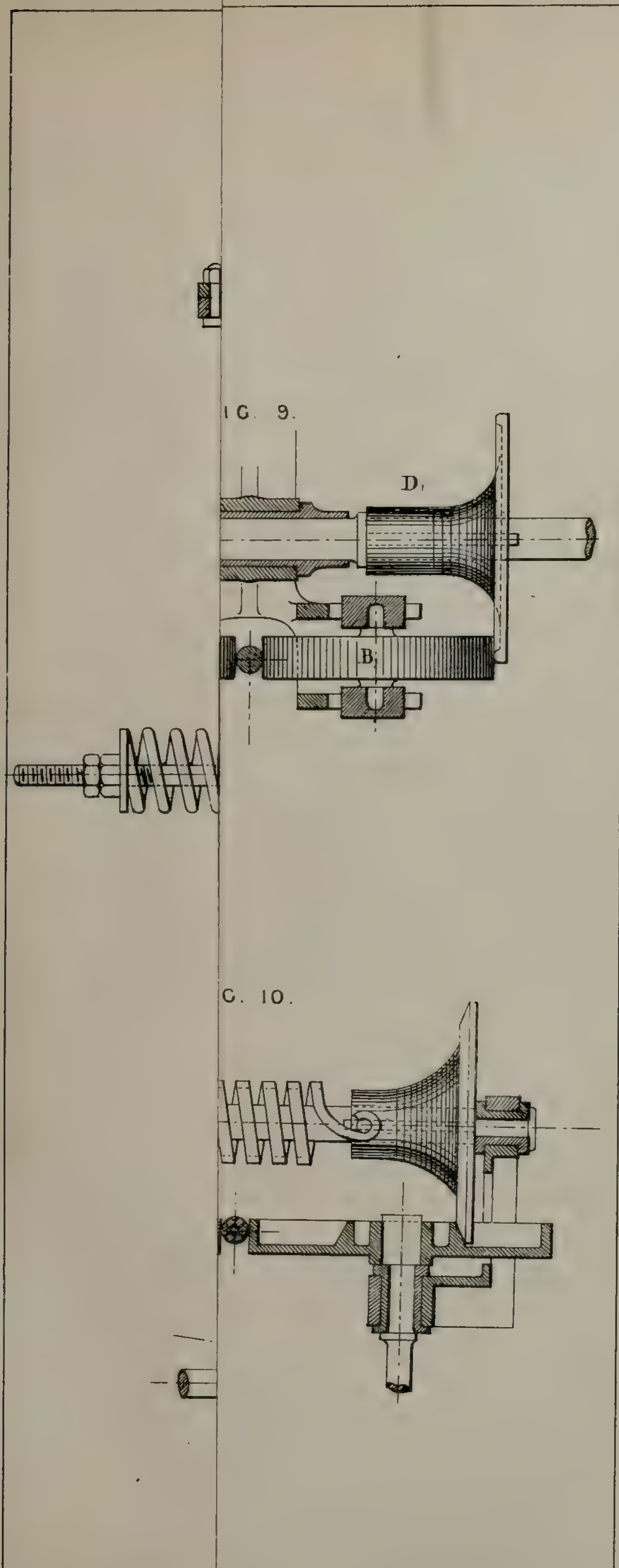

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FIG. 6

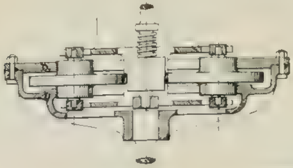


FIG. 9

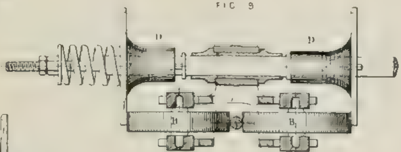


FIG. 7

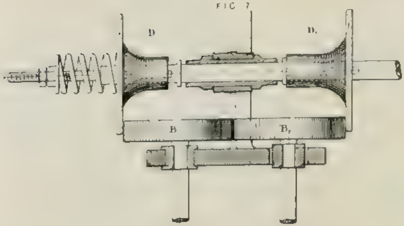


FIG. 10

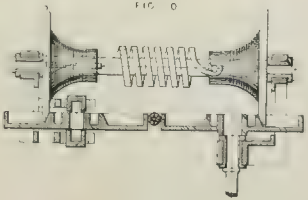
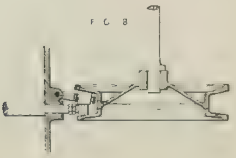


FIG. 8



Illustrating Professor H.C. Fleeming Jenkin's Paper on Nest Gearing

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—
Professor Henrici, Ph.D., F.R.S., President of the London Mathematical Society.

THURSDAY, SEPTEMBER 20.

The President delivered the following Address:—

On reading through the addresses delivered by my predecessors in this office, I was struck by the fact that in nearly every case the speaker began with a lamentation over his unfitness for the work before him, and those seemed to me to be the more eloquent on these points who showed by their address that they least needed an excuse. The amount of excuse given appears in fact to be directly proportional to the gifts of the speaker, and hence inversely proportional to the need of such an excuse.

Under these circumstances I cannot express my sense of my own unfitness for this post better than by saying nothing about it. I must, however, beg your indulgence for my shortcomings, both as regards my address and my manner of conducting the general business of this section.

As the Presidential chair is occupied by one of the most illustrious of mathematicians, it would be presumptuous for me to attempt to give an account of the recent progress of mathematics. I propose only to speak for a short time on that part of mathematics which has always been most attractive to myself—that is, pure geometry as apart from algebra, but I shall confine myself to some considerations relating to the teaching of geometry in this country. Pure geometry seems to me to be of the greatest educational value, and almost indispensable in many applications; but it has scarcely ever been introduced at Cambridge, the centre of mathematics and mathematical education in England.

The number of geometrical methods now in use is astonishingly great. These differ on the one hand according to the nature of the result aimed at, but on the other according to the amount of algebra employed, and to the relation in which this algebra stands to the pure '*Anschauung*.' I use the word *Anschauung* because I know of no English equivalent; the German word has the philosophic meaning rendered by intuition, and retains its original concrete meaning of looking at a thing, and might perhaps be translated: intuition by inspection. It is the inspection of figures which is of the greatest importance in geometry. It is hereby of little consequence whether the figures are seen by the physical eye or only mentally; because the conception of that space in which we perceive everything and without which we can perceive nothing, which therefore is, according to Kant, a form of our *Anschauung*, is built up in our mind through many generations in conformity with sensual impressions.

It would be of interest, if time permitted, to follow up the gradual development and extension of geometry into the wider science of algebra, from the first introduction of the latter in the theory of proportion to the present state, where there exists really no essential difference between the two, where geometry is only one manifestation of algebra, but so complete a one, that at least within its number of dimensions it again contains algebra.

In some of the methods just referred to, no algebra is used at all, whilst others may be distinguished according to the nature of the algebra used, whether

equations containing 1, 2, 3, or more variables are employed. In such a division, Von Staudt's system, without a vestige of algebra, would occupy the one end, and the purely algebraical theory of invariants with geometrical interpretation the other.

There is, however, not only a difference in the amount of algebra used, but, if possible, a greater one in the manner in which the symbols are interpreted. And it is here that algebra has apparently the greater power. One algebraical theorem, by being read in different ways, by giving ever different meanings to the symbols, reveals a variety of geometrical and other theorems. We have in it the crystallised form, the very essence of the mathematical truth, but in the most abstract form conceivable. Now this most abstract form is the highest and the most perfect which mathematical truth as such can assume, and which it must assume before a theory is really complete in the eyes of a pure mathematician. It is only in this shape that it is ready to be turned to account in any direction where it may be needed.

In thus placing algebra on the highest pinnacle, the reasons will be apparent which will make many mathematicians, not to mention others, prefer the truths it reveals cast in a mould which connects them with concrete things rather than with abstract notions. In fact, to be thoroughly at home in the highest theories of pure algebra requires some of the genius of men like Cayley and Sylvester who have founded, and to a great extent built up, modern algebra. But even they constantly make use of geometry to assist them in their investigations, and no one could have expressed this more strongly than Professor Sylvester himself in his brilliant address delivered from this chair at the Exeter meeting of our Association.

If this is so, surely every progress in the spread of the knowledge of pure geometry should be welcomed and encouraged; but in England pure geometry is almost unknown excepting in the elements as contained in Euclid and in the old-fashioned geometrical conics. The modern methods of synthetic projective geometry as developed on the Continent have never become generally known here. The few men who have thoroughly made themselves acquainted with them, and who have preferred purely geometrical reasoning, have not belonged to Cambridge, and have thus stood somewhat outside the national system of training mathematical teachers. The late Professor Smith introduced these methods at Oxford, and there was some expectation that he would have written, if he had been spared, a text-book which might have done much to introduce the subject more widely. His principal mathematical work lay, however, in another direction.

The one English mathematician whose mathematical thought is purely geometrical is Dr. Hirst, a pupil of Steiner, who in the position which he has just relinquished has been able to introduce, as the first, modern geometrical methods into a regular system of professional education, whilst showing at the same time by his original work what can be done with these methods.

Other mathematicians who have studied these methods—and I believe there are many—have made use of them by translating the geometrical into algebraical reasoning.

Towards the early possibility of such a translation much was done by the labours of the late Mr. Spottiswoode, who years ago wrote the first connected treatise on the theory of determinants, and who up to the last few years employed some of his leisure hours in working out geometrical problems, the work consisting always of some beautiful piece of algebra.

It is not often that our section has to mourn in one year the loss of two such men as Smith and Spottiswoode.

It is easy to see how the neglect complained of has come to pass. In England when mathematics, after having lain dormant for about a century, began to revive, the first necessity was to become acquainted with the enormous amount of work meanwhile done on the Continent. This acquaintance was made through France, at that time nearly all the standard works being in the French language, which was at the same time the language best known to English students. The subjects principally taken up were the calculus and its application to mechanics. And I believe I am not far wrong when I say that the wonderful writings of Lagrange

with their extraordinary analytical elegance had the greatest influence. But in his works anything geometrical was studiously avoided. Lagrange prided himself that there was no figure in his 'Mécanique analytique.'

The best analytical methods of the Continent were thus introduced into England, rapidly assimilated and made the foundation of new theories, so that the mathematical activity in this country is now at least as great as it ever has been anywhere.

But whilst analysis, algebra, and with it analytical geometry, made rapid progress, pure geometry was not equally fortunate. Here the hold which Euclid had long obtained, strengthened, no doubt, by Newton's example, prevented any change in the methods of teaching.

Most of all, perhaps, solid geometry has suffered, because Euclid's treatment of it is scanty, and it seems almost incredible that a great part of it—the mensuration of areas of simple curved surfaces and of volumes of simple solids—is not included in ordinary school teaching. The subject is, possibly, mentioned in arithmetic, where, under the name of mensuration, a number of rules are given. But the justification of these rules is not supplied, except to the student who reaches the application of the integral calculus; and what is almost worse is that the general relations of points, lines, and planes, in space, is scarcely touched upon, instead of being fully impressed on the student's mind.

The methods for doing this have long been developed in the new geometry which originated in France with Monge. But these have never been thoroughly introduced.

Works written in the German language naturally received even less attention. But it was in Germany, at the beginning of the second quarter of this century, that geometry received at the hands of several masters an impulse which put the subject on an entirely new footing.

I may mention here especially four men of whom each invented a new method and established a new system of geometry. Two of these, Möbius and Plücker, still use algebra, but in perfectly new and original manners, which, although very different from each other, have this in common, that in both we have not algebra interpreted geometrically, but rather geometry veiled in an algebraic garb. The geometrical meaning is never lost sight of.

But perfectly independent of algebra was the great Steiner, the greatest geometrician since the times of Euclid, Appolonius, and Archimedes. In his celebrated 'Systematische Entwickelungen' he has laid the foundation of a pure geometry, on which a wonderful edifice has since been raised. His treatment of the principle of duality, and his methods of generating conics by projective, or homographic, rows and pencils which have been extended to curves of all degrees, have given to geometrical reasoning a generality never before dreamed of. He is in one respect the opposite of Lagrange, hating and despising analysis as much as ever Lagrange disliked pure geometry. Steiner started from the geometry of the Greeks, Euclid's elements, and a few other *metrical* properties he takes for granted; but then he goes on with essentially modern methods of his own to investigate what are now called projective properties of curves and surfaces.

This metrical foundation Von Staudt changed. In his 'Geometrie der Lage,' published fifteen years after Steiner's 'Entwickelungen,' he established a most remarkable and complete system, into which the notion of a magnitude does not enter at all. He shows that projective properties of figures, which have no relation whatsoever to measurements, can be established without any mention of them. He goes so far as even to give a geometrical definition of a number, in its relation to geometry as determining the position of a point, in his theory of what he calls 'Würfe'; and one of the most interesting parts of his work is the purely geometrical treatment of imaginary points, lines, and planes.

In the hands of these men, and since their time, pure geometry has become a most important instrument for research, rivalling in power the more or less algebraical methods, and surpassing them all in the manner in which they raise before the mind's eye a clear realisation of the forms and figures which are the object of the investigation.

In close connection with these methods stand descriptive geometry and geometrical drawing, which teach how to represent figures on a plane or other surface. These have been treated as arts unknown at English universities, and relegated to the drawing office. Instead of this they ought to be an essential and integral part of the teaching of geometry in connection with the purely geometrical methods.

As far as the progress of science is concerned, this neglect of pure geometry in England has been of little consequence—perhaps it has rather been a gain. For science itself it is often an advantage that a centre of learning becomes one-sided, neglects many parts in order to concentrate all its energy on some particular points, and make rapid progress in the directions in which these lie. At present, when mathematics flourishes as never before, when almost every nation, however small, has its eminent mathematician, there are so many such centres that what is neglected at one place is pretty surely taken up and advanced at another. But what may suffer, if one side of a science is not cultivated in a country, is the industry which would have gained by its applications.

In considering the teaching of any mathematical or other scientific subject, we cannot at the present time neglect the wants of the ever-increasing class of men who require what has been called technical education. Among these, the large number who want mathematics at all require geometry much more than algebra and analysis, and geometry as applied to drawing and mensuration.

This want has been supplied by the numerous science classes spread over the country, with their head-quarters at the Science and Art Department at South Kensington, whose examinations—now, however, put in competition with those of the City and Guilds of London Institute, and others—have pretty much guided and regulated the teaching. A great deal of good has thus been done, but there is still much room for improvement. The teaching of geometry especially, as judged by the text-books which have come before me, is somewhat deplorable. And this is so, principally, because the spirit of Euclid and the methods of the ancient Egyptians and Greeks, rather than the fundamentally different ideas and methods of modern geometry, still rule supreme; though the latter have had their origin partly in technical wants.

In what is called Geometrical Drawing, or Practical Geometry, for instance, there are first given a number of elementary constructions—such as drawing parallels and perpendiculars, or bisecting the distance between two given points. They are solved by aid of those instruments only which Euclid knew—viz. the pair of compasses for drawing circles, and the straight-edge for drawing straight lines. But there is no draughtsman who would not, as a matter of course, use set squares for the former problem, and solve the latter by trial rather than by construction. Then again there come constructions like the division of the circumference of a circle into seven parts, which cannot be solved accurately, but which is very easily solved by trial. Instead of that, a *construction* is given which takes much more time, and is by no means more accurate. For, after all, our lines drawn on the paper are not without thickness, so that, for this reason alone, every part of the construction is affected by some small error; and it is absurd to employ a construction, though theoretically true for ideal figures as conceived in our mind, in preference to a much simpler one which, within our practical limits, is equally, or perhaps more, correct.

This is very much like the manner in which I found problems on decimal fractions treated by the candidates for the Matriculation Examination at the London University, and which reflected little credit on the manner in which the important subject of decimals is handled at our schools. It is so characteristic that I may be excused for giving it here. The problem, for instance, being to give the product of two decimal fractions, exact to, say, four decimals, each of the factors having the same number of places. This was almost regularly performed as follows. First, the decimals are converted into vulgar fractions, then these are duly multiplied, numerator by numerator, and denominator by denominator, and then the resulting fraction is again converted to a decimal, with as many places as it may yield, and, lastly, of these the first four are taken and put down, duly marked *Answer*. Or a candidate,

standing however on a far higher level, multiplies both decimals out in the proper fashion, but to eight places, and cuts off four places at the end. No wonder that the public at large will hear nothing of the decimal system of weights and measures if the very essence of the decimal system of numbers is so little understood by the men who have to train the minds of the young generation!

I need scarcely say that I do not mean to blame the Science and Art Department, far less the teachers who have simply to follow suit. They act up to their light, and cannot be expected to introduce methods which are practically unknown at Cambridge, and of which the only good text-books are in foreign languages; books which are probably not at all suitable for introduction into our schools without considerable change.

It is satisfactory to learn that an association has recently been formed under the presidency of Professor Huxley 'to effect the general advancement of the profession of science and art teaching by securing improvements in the schemes of study, and the establishment of satisfactory relations between teachers and the Science and Art Department, the City and Guilds of London Institute, and other public authorities.'

The good wishes of all who have the cause of sound education at heart must go with such an undertaking, one of the principal aims of which seems to be to save teaching from being any longer enslaved by examinations, and to promote greater accord between the teacher and the examiner. It is to be hoped that this association will consider geometry as one of the subjects included under the designation of science.

It is by the neglect of pure geometry and its applications to geometrical drawing that Cambridge has lost, or rather has never had, contact with the practical needs of the nation. All the marvels of modern engineering have sprung into existence without its help. The great engineers have had to depend to a degree, now unheard of, upon costly experiments, until they themselves gradually discovered mathematical methods adapted to their purposes.

Only the electrical engineer found ready to his hands a complete theory of which the mathematical part has been to a very great extent developed at Cambridge, or by men who have had their mathematical training there. This theory is, however, in its very nature less geometrical. One at least of the great men to whom the present theory of electricity is due, the late Clerk Maxwell, had the keenest appreciation of the value of modern geometry. I remember a characteristic letter of his being read to the Council of the London Mathematical Society, in which the writer, forgetting the subject of his letter, burst out into an enthusiastic praise of a German text-book, the 'Geometrie der Lage,' by Reye, through which Maxwell evidently, for the first time, got any idea of this subject.

The engineer will always prefer geometrical methods to analysis, and has invented for himself a great variety of them. Originally these are disjointed, being invented for special purposes. It is the business of the mathematician afterwards to connect, simplify, and extend them, as has been done to a great extent by Culmann in Zürich, or by Cremona at the Polytechnic School at Rome.

Of these methods a few may be mentioned. First of all the geographical determination of stresses in certain girders invented both by mathematicians and by engineers. Its application is so simple that no engineer will ever use any other method if once he knows this one. It is so well adapted to its purpose, that I venture to say that a simpler method is impossible, being fully aware how dangerous such a statement is. Nay, if I were asked to give the formulæ to obtain the stresses by calculation, I should write these down from a sketch of the diagram, this being the simplest way of obtaining them.

Another problem which recurs again and again is the determination of the area of a figure representing perhaps a plot of land or the section of a beam. Here also the advantage is altogether on the side of the graphical method.

It is unnecessary to multiply these examples. But to make full use of graphical methods the draughtsman ought to have a thoroughly geometrical education. For instance, the real nature of the reciprocal diagrams already mentioned is only understood by aid of a peculiar reciprocal relation between points and planes in

space closely connected with the theory of the linear complex, as has been shown by Cremona.

I have mentioned already the 'Analytical Mechanics' of Lagrange, which is without any trace of geometry, although there is scarcely a branch of applied mathematics which is in its very nature more geometrical. In fact one part of it, now separated as kinematics, treats solely of changes in position and shape of geometrical quantities, and differs from pure geometry only in this, that the changes are considered as referring not to space alone, but also to time.

What mechanics gains by introducing geometry to the full will be apparent to all who have become acquainted with modern Continental text-books on the subject.

Let us compare the analytical with the geometrical reduction of a system of forces acting on a rigid body, or, to use Clifford's nomenclature, the reduction of a system of rotors, which may represent either forces or rotations, or any other quantities which have certain fundamental properties in common with those, so that they may be represented by rotors. In the analytical process the system is reduced to a rotor and a vector, that is a resultant force and a couple. In the geometrical treatment we see that this is only one way of reducing the rotors to two, viz. the one which is best fitted to be treated by analysis. But there is a multitude of other reductions. These all appear as of equal importance in the geometrical method. Furthermore, this method shows us in the simplest way possible how all the line pairs which may be the lines of action of two resultant rotors, although there are infinities of infinities of such pairs, are arranged in space, so that one gets a clear picture of all these reductions in one's mind.

Again, compare Möbius' geometrical investigation of the rays of light passing through a system of lenses with that of Gauss, whose very name suggests simplicity and elegance. The celebrated 'cardinal points' appear in Gauss' original paper as the result of a somewhat long though certainly elegant analysis, whilst by Möbius they are the natural outcome of his geometry, so that any student once started on this method is bound to come across these points, or rather across pairs of points, of which the cardinal points of Gauss are only one special case. The whole is, in fact, contained in the following easily proved proposition: the rays of light starting from a point in the axis of the system before entering the first lens, and after leaving the last, form two homographic pencils in perspective position.

This is only one small part of the advantage which optics can derive from geometry.

That the old-established mode of teaching the elements of geometry based on Euclid requires a thorough and fundamental change has been often acknowledged, among others, at Exeter and Bradford, by two of the most eminent mathematicians who have occupied this chair, and besides by the many teachers who constitute the Association for the Improvement of Geometrical Teaching, which itself grew out of the action of our section. I know therefore of no opportunity better suited to review the progress made in this direction than the present one, as the subject has on several occasions occupied the attention of our section. Nevertheless I have hesitated at entering on this somewhat delicate question, because I fear that I have little to offer but criticism, which might seem hostile to the Association just named. But I hope that the many earnest workers, who have devoted much time and thought to the drawing up of syllabuses on different parts of our subject, will excuse the remarks of one who has himself tried his hand at the same work, and who therefore may be supposed somewhat to know the difficulties that have to be overcome.

When the syllabus on the elements of plane geometry appeared, I resolved to give it a thorough trial, and took the best means in my power to form an opinion on its merits, by introducing it into one of my classes. The fact that it did not quite satisfy me, and that I gave up its use again, does not, of course, prove that it fails also for use in schools, for which it was originally intended.

Let me add that the more I have become acquainted with the difficulty of the whole subject, the greater has become my admiration for Euclid's book, whilst my conviction of its unfitness as a school book has equally gained in strength.

In considering the merits of Euclid as a text-book, it is desirable to distinguish clearly between the general educational value of its teaching and the gain of geometrical knowledge. It is with the latter chiefly that I am concerned, whilst it is, of course, through the former that Euclid has got so firm a hold at all schools; and to the great majority of boys this is undoubtedly of most importance, and no reform would have the slightest chance of becoming generally introduced which neglects this. But improvement in both directions may well go together, and the logical reasoning employed in Euclid would gain to many boys much, both in clearness and interest, if the subject-matter reasoned about became in itself better understood.

Probably a great deal could be done by introducing some of the elements of logic into the teaching of language. I have been assured by an eminent scholar that the laws of forming a sentence—the fact that a sentence in its simplest form consists of subject, object and copula, was not explained in English schools. If this grammatical part of logic were properly treated of in connection with language, and if at the same time acquaintance with geometrical objects, particularly through the medium of geometrical drawing and the many methods used in the Kindergartens, were more secured, then a systematic course of geometry would become both easier and more useful.

Much indeed may be done by introducing simple geometrical teaching into the nursery, and into the earliest instruction of children, following the example of the Kindergarten, and it is pleasing to see that the latter are rapidly gaining ground in England. It is true that these schools may still be improved. In geometry they seem to, and perhaps at present are bound to, work mostly towards Euclid. But many able men and women are actively engaged in perfecting them, and it is of interest to know that Clifford had it in his mind to write a geometry for the nursery and the Kindergarten.

In a curious contrast to the mode of teaching geometry stands that of teaching algebra. In the first everything is sacrificed to logic. Axioms and definitions without end are given, though to the beginner a more rapid dive into the subject would be much more suitable. In algebra, on the other hand, the boy is at once plunged into the midst of it. No axiom is mentioned. A number of rules are stated, and the schoolboy is made to practise them mechanically until he can perform, and that often with considerable skill, a number of most complicated calculations—but calculations which are often of very little use for actual application. Simplifications of equations follow in senseless monotony, until the poor fellow really thinks that solving a simple equation does not mean the finding of a certain number which satisfies the equation, but the going mechanically through a certain regular process which at the end yields some number. The connection of that number with the original equation remains to his mind somewhat doubtful. Then there are processes, like the finding of the G. C. M., which most of the boys never have any opportunity of using, excepting, perhaps, in the examination room. A more rational treatment of the subject, introducing from the beginning reasoning rather than calculation, and applying the results obtained to various problems taken from all parts of science as well as from everyday life, would be more interesting to the student, give him really useful knowledge, and would be at the same time of true educational value.

The chief progress in geometrical teaching has to be sought in the introduction of modern ideas and methods into the very elements, and modern teaching ought to take full account of this.

In favour of this view I might bring forward the opinions of many teachers and mathematicians from England, as well as from abroad, but I will confine myself to one quotation. Professor Sylvester gives his opinion thus: 'I should rejoice to see mathematics taught with that life and animation which the presence and example of her young and buoyant sister (viz., natural and experimental science) could not fail to impart, short roads preferred to long ones, Euclid honourably shelved or buried "deeper than did ever plummet sound" out of the schoolboy's reach, morphology introduced into the elements of algebra—projection, correlation, motion accepted as aids to geometry—the mind of the student

quickened and elevated and his faith awakened by early initiation into the ruling ideas of polarity, continuity, infinity, and familiarisation with the doctrine of the imaginary and inconceivable. It is this living interest in the subject which is so wanting in our traditional and mediæval modes of teaching.'

If from this point of view we now look towards the work of the Association for the Improvement of Geometrical Teaching, the result is not so satisfactory as might have been wished. There is very little of the influence of modern ideas to be found in the different syllabuses which have been published. Even in the one headed 'Modern Geometry' there is nothing of the genius of modern thought. The subject-matter is partly taken from modern geometry, but for modern methods one looks in vain. In the geometrical conics, too, one would like to see Steiner's generation of conics, but of these there is no trace.

Nevertheless, it is satisfactory to see that the use of the syllabus on plane geometry has spread pretty widely, and it is to be hoped that it will continue to do so. A thorough reform, in the direction indicated, will be a difficult task, and it will perhaps be a long time before it is possible. At present it has not even been settled which series of axioms will ultimately be adopted. Of the various systems which have been proposed since the investigations of Riemann and Helmholtz, I may mention here Clifford's suggestion to replace Euclid's axiom about parallels by the new one, which maintains that in a plane similar figures exist, or, more completely, that at any part in a plane a figure is possible which is similar to any given figure in that plane. This axiom is somewhat startling as long as we have the usual theory of similar figures in our mind. But the notion of similar figures is truly axiomatic, and it has lately become my conviction that this axiom may be extremely fruitful, and the working out of a syllabus of plane geometry based on it would be very desirable.

Possibly many such attempts have still to be made before a new Euclid finds the materials sufficiently prepared for him to raise the hoped-for edifice.

The following Report and Papers were read:—

1. *Third Report of the Committee on Meteoric Dust.*—See Reports, p. 126.

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2. *On some Spectroscopic Appliances.* *By* Professor ARTHUR SCHUSTER, *F.R.S.*

The author exhibited a rotating spark-holder which could be adjusted by the observer at the eye-piece of the spectroscope, and thus allowed spectra of different bodies to be brought into the field of view in rapid succession.

He also exhibited a modified simple form of Mermet and Déchanel's fulgurator for the examination of spectra of liquid bodies.

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3. *On the Absorption Spectrum of Didymium Chloride.* *By* Professor ARTHUR SCHUSTER, *F.R.S., and* T. G. BAILEY.

The authors have examined the absorption-spectrum of crystals of didymium chloride by polarised light, and have found differences similar to those which Bunsen discovered in the sulphate. They propose to extend their observations to other didymium sulphate, and defer a full discussion of the comparison of the different spectra until more material has been collected.

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4. *On the Cause of Crystalline Form.* *By* G. JOHNSTONE STONEY, *F.R.S.*

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5. *A specimen of the Work of the new Chronograph at Dunsink Observatory.* *By* Professor ROBERT S. BALL, *LL.D., F.R.S.*

6. *Experiments in Bolometry.* *By* Professor SILVANUS P. THOMPSON.

Hitherto the bolometers devised by Langley and others have been constructed of thin metal films blackened with lamp-black or platinum-black. Abstract considerations show, however, that to have a maximum degree of sensitiveness the conductor employed should be one in which the change of electric resistance per degree of temperature is the greatest; it should also have as small a thermal capacity as possible, and its exposed surface should be its only conducting part. Theoretically, therefore, a carbon-film in some high-conducting form should be the best. Pending the preparation of special carbon-films the author had made some experiments on the strips and filaments of carbon which are to be found in incandescent lamps. The resistance of these, when carefully measured on a Kirchhoff's bridge, was found to be considerably less when exposed to radiation than when kept in the dark, the change of resistance in some cases amounting to 3 per cent. of the total resistance. The cylindrical filaments and rectangular strips used in most lamps are not, however, well adapted to show the bolometric effect, as their exposed surface is small as compared with the area of the cross-section of the conductor.

These observations suggest the following points:—

(1) That measurements made for specifying the resistances of such lamps should be conducted in the dark.

(2) That a carbon-film, or even a carbon-lamp, may serve as the receiving part of a photophone.

(3) That probably the effects obtained by Dr. Börnstein with metals might be re-observed if the metal films were very thin.

(4) That special films of good-conducting carbon should be applied in standard bolometers.

(5) That a true standard photometer might be constructed on the bolometric principle, having the sensitive conducting film covered with *pigmentum nigrum* from the human eye. Such an instrument ought to be sensitive to precisely the same rays as the eye itself, and in identically relative proportions for different rays.

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7. *On the Equations of Motion and the Boundary Conditions for Viscous Fluids.* *By* Professor OSBORNE REYNOLDS, *F.R.S.*

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8. *Suggestions for facilitating the use of a delicate Balance.* *By* Professor LORD RAYLEIGH, *F.R.S.*

In some experiments with which I have lately been occupied a coil of insulated wire, traversed by an electric current, was suspended in the balance, and it was a matter of necessity to be able quickly to check the oscillation of the beam, so as to bring the coil into a standard position corresponding to the zero of the pointer. A very simple addition to the apparatus allowed this to be done. The current from a Leclanché cell is led into an auxiliary coil of wire, coaxal with the other, and is controlled by a key. When the contact is made, a vertical force acts upon the suspended coil, but ceases as soon as the contact is broken. After a little practice the beam may be brought to rest at zero at the first or second application of the retarding force.

This control over the oscillations has been found so convenient that I have applied a similar contrivance in the case of ordinary weighings, and my object in the present note is to induce chemists and others experienced in such operations to give it a trial. Two magnets of steel wire, three or four inches long, are attached vertically to the scale-pans, and underneath one of them is fixed a coil of insulated wire of perhaps 50 or 100 turns, and of 4 or 5 inches in diameter. The best place for the coil is immediately underneath the bottom of the balance-case. It is then pretty near the lower pole of the magnet, and is yet out of the way. The circuit is completed through a Leclanché cell and a common spring contact-

key, placed in any convenient position. The only precaution required is not to bring other magnets into the neighbourhood of the balance, or at any rate not to move them during a set of weighings.

The other point as to which I wish to make a suggestion relates to the time of vibration of the beam. I think that, with the view of obtaining a high degree of sensitiveness, the vibrations are often made too slow. Now the limit of accuracy depends more upon the smallness of the force which can be relied upon to displace the beam in a definite manner than upon the magnitude of the displacement so produced. As in other instruments whose operation depends upon similar principles, e.g. galvanometers, it is useless to endeavour to increase the sensitiveness by too near an approach to instability, because the effect of casual disturbances is augmented in the same proportion as that of the forces to be estimated. If the time of vibration be halved, the displacement due to a small excess of weight is indeed reduced in the ratio of four to one, but it is not necessarily rendered any more uncertain. The mere diminution in the amount of displacement may be compensated by lengthening the pointer, or by optical magnification of its motions. By the method of mirror-reading such magnification may be pushed to almost any extent, but I am dealing at present only with an arrangement adapted for ordinary use.

In the balance (by Oertling) that I am now using, the scale-divisions are finer than usual, and the motion of the pointer is magnified four or five times without the slightest inconvenience by a lens fixed in the proper position. The pointer being in the same plane as the scale-divisions, there is no sensible parallax. In this way the advantage of quick vibrations is combined with easy visibility of the motion due to the smallest weights appreciable by the balance.

To illuminate the scale the image of a small and distant gas flame is thrown upon it by means of a large plate-glass lens. This artificial illumination is found to be very convenient, as the instrument stands at some distance from a window, but it is not at all called for in consequence of the use of the magnifying lens.

FRIDAY, SEPTEMBER 21.

The following Reports and Papers were read :—

1. *Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements.*—See Reports, p. 41.

2. *On a case of Rapid Diffusion of Molten Metals. By* Professor CHANDLER ROBERTS, *F.R.S.*

The question of the diffusion of metals, recently attacked by Dr. Guthrie at the ordinary temperature in the case of amalgams of mercury, has been examined by Professor W. Chandler Roberts, who has dealt with metals having a higher melting point than lead. He shows by a series of careful experiments that while molten copper and antimony interpenetrate but slowly, the 'mobility' of gold and silver in molten lead is comparatively rapid. Exact numerical determinations of the rate of passage have yet to be made, but the velocity of gold and of silver in molten lead is so great as to resemble the diffusion of gases rather than the diffusion of a solid in a liquid. Professor Roberts has already extended his observations to silver and gold in molten bismuth, and, as Sir W. Thomson observed, the question is one of extreme importance and interest both to the physicist and metallurgist.

3. *On the Magnetic Susceptibility and Retentiveness of Soft Iron. By* Professor J. A. EWING, *B.Sc., F.R.S.E.*

During three years the writer has been engaged, while in Japan, in prosecuting researches on the magnetisation of iron and steel, and on the effects of stress on

magnetic susceptibility and thermo-electric quality. Preliminary notices of some of his earlier results have appeared in the 'Proceedings of the Royal Society' (Nos. 214 and 216, 1881, and No. 220, 1882), but a detailed account of the work has still to be given. Meanwhile the following points, not previously noticed, are perhaps of sufficient interest to warrant their separate publication.

In the experiments on magnetisation iron and steel wires were used, either welded into rings or in the form of straight pieces whose length was great enough to make the influence of the ends negligible. Curves were obtained, in some cases by the ballistic method and in some by the direct magnetometric method, showing the changes of magnetisation which occurred when magnetising force was gradually applied, withdrawn, reapplied, reversed, and so on.

The results of many experiments with several specimens of carefully annealed soft iron wires have shown that they possess, in very high degree, a property not generally credited to soft iron—the property of remaining strongly magnetic when the magnetising force is removed.

As an example, the case may be cited of an annealed iron wire which was subjected to a magnetising force of 22·4 c.g.s. units. This gave it a magnetic induction amounting to 16,000 c.g.s. units, corresponding to a magnetisation of 1,270. When the magnetising force was removed (gradually and completely) the induction fell only to 15,000. In other words, the intensity of residual magnetisation was equal to nearly 1,200 c.g.s. units.

Here more than 93 per cent. of the whole induced magnetisation survived the removal of the magnetising force; and in many other cases the residual magnetism amounted to nearly 90 per cent. The somewhat extraordinary spectacle was thus presented of a piece of soft iron, entirely free from magnetic influence, and nevertheless holding an amount of magnetism far in excess of what is ever held by a permanent magnet of the best tempered steel.

In this condition, however, the magnetic character of the iron is highly unstable. The application of reverse magnetising force quickly causes demagnetisation, and the slightest mechanical disturbance has a similar effect. Gentle tapping removes nearly all the residual magnetism. Variations of temperature reduce it greatly, and so does any application of stress. On the other hand, if the iron be carefully protected from disturbance it seems that the residual magnetism disappears only very slowly, if at all, with the mere lapse of time.

If, after magnetisation, the magnetising force be suddenly removed, the residual magnetism is (as might be expected) considerably less than when the force is removed gradually.

The ratio of residual to total magnetisation is always small when the intensity of magnetisation is small, and passes a maximum when the intensity is increased. This maximum is particularly distinct in wires which have been hardened by stretching, but it occurs also in soft annealed wires. In one instance, where the wire had been hardened by stretching, the maximum ratio of residual to total magnetism was 0·60, which was given by applying and removing a magnetising force of about 10 c.g.s. units, but on the application of a force of 90 units the ratio fell to 0·33. With steel the maximum in this ratio is less sharp, but still distinct. Neither in hard iron nor in steel is the ratio, even at its maximum, so great as in soft iron, where (as has been said above) it frequently reaches 0·9.

During the first magnetisation of soft iron wires the ratio (κ) of intensity of magnetisation (I) to magnetising force was generally about 200, sometimes nearly 300. And by gently tapping the wire during the application of magnetising force this coefficient was on one occasion raised to the enormous value of 1,590. In the case alluded to the magnetisation went on so rapidly, as the magnetising force was increased, that a force of 1 c.g.s. unit gave an induction of 10,000.

In this and other particulars the experiments have been strongly confirmatory of the idea that there is, in soft iron, a static frictional resistance to the rotation of the magnetic molecules, which is the principal cause of the remarkable retentiveness described above, and which is overcome by mechanical agitation.

Numerous measurements have been made of the energy expended in taking iron and steel through cyclic changes of magnetisation. For example, in changing

the magnetism of one specimen of annealed iron wire from $I = 1250$ to $I = -1240$, and back, the amount of work done against magnetic friction (apart from any induction of currents) was 1,670 centimetre-dynes per cubic centimetre of the metal. In hardened iron, and especially in steel, the work done is far greater.

The effects of stress on existing magnetism and on magnetic susceptibility have been examined at great length. The most remarkable effects occur in wires which have been hardened by stretching. In these the presence of a moderate longitudinal tensile stress increases the magnetic susceptibility immensely for low values of the magnetising force, but diminishes it for higher values. It also increases, very greatly, the ratio of residual to total magnetisation; but both of those effects pass a maximum when the stress is sufficiently increased.

The whole subject is much complicated by the presence of the peculiar action which, in previous papers, the writer has named *hysteresis*, the study of which, in reference both to magnetism and to thermo-electric quality, has formed a large part of his work.

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4. *On Maxwell's Equations for the Electro-magnetic Action of Moving Electricity. By* Professor FITZGERALD, *F.R.S.*

Maxwell only once mentions this action in his 'Treatise on Electricity and Magnetism,' in § 768, although it is just as necessary as his displacement-currents in order to be able to consider all circuits as closed.

The equations for the electro-magnetic field, § 618, are incomplete, for he introduces as the coefficient of e in the equations for the mechanical force $-\frac{d\psi}{dx}, -\frac{d\psi}{dy}$, and $-\frac{d\psi}{dz}$ in its three components, while it would be more complete to have put in P, Q, R the complete components of the electromotive force. By so doing he would have introduced the terms $c(e\dot{y}) - b(e\dot{z})$, which are evidently the terms expressing the convective action. Maxwell himself practically makes this substitution in § 631 and deduces indirectly his electro-magnetic theory of light from the term $-e\frac{dF}{dt}$ thereby introduced.

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5. *On the Energy lost by Radiation from Alternating Electric Currents. By* Professor FITZGERALD, *F.R.S.*

I take the simple case of a small circular current.

The components of the vector potential at any point must satisfy $\Delta^2 F + K\mu\ddot{F} = 0$, while for points very close to the elements of currents they must be $F = \mu\frac{u}{r}$

Assuming the current simply periodic, $c = c_0 \cos 2\pi\frac{t}{T}$, then

$$F = \mu\int\frac{u_0 \cos \frac{2\pi}{T}(t - \sqrt{K\mu}.r)}{r}ds.$$

The energy in any element of the field is per unit volume $= Fu + Gv + Hw$, and as $u = -\frac{K}{4\pi}\ddot{F}$, &c., we can easily represent in the form of the square of the above integral the energy per unit volume. Estimating it for the case of a very small circular current, it gives for the energy at any time on a sphere of radius R—

$$E = (\pi a^2 c_0)^2 \frac{\mu}{6} e^2(e^2 + R^{-2}),$$

where a is the radius of the small circuit and e is $\frac{2\pi\sqrt{K\mu}}{T}$.

The part of this independent of the radius of the sphere is evidently the radiated energy, and assuming it to move with the velocity of the waves, we find the energy radiated per second

$$e = (\pi a^2 c_0)^2 \frac{8\mu\pi^4}{3T^4V^3},$$

when V is the velocity of wave-propagation $= \frac{1}{\sqrt{K\mu}}$. This is very small indeed unless the period T be excessively small.

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6. *On a Method of producing Electro-magnetic Disturbances of comparatively Short Wave-lengths. By* Professor FITZGERALD, *F.R.S.*

This is by utilising the alternating currents produced when an accumulator is discharged through a small resistance. It would be possible to produce waves of as little as 10 metres wave-length, or even less.

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7. *Gyrostatic Determination of the North and South Line, and the Latitude of any place. By* Sir WILLIAM THOMSON, *F.R.S.*

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8. *On a Model illustrating Helicoidal Asymmetry, and particularly the formation of Right- and Left-handed Helicoidal Crystals from a non-Helicoidal Solution. By* Sir WILLIAM THOMSON, *F.R.S.*

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9. *Report of the Committee for the Harmonic Analysis of Tidal Observations.*—See Reports, p. 49.

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10. *On the Attractive Influence of the Sun and Moon causing Tides, and the Variations in Atmospheric Pressure and Rainfall causing Oscillations in the Underground Water in Porous Strata. By* ISAAC ROBERTS, *F.G.S., F.R.A.S.*

The investigations have been made at Maghull, which is an agricultural district about eight miles to the north-east of Liverpool, and relate to movements in the underground water of the Triassic rocks, which lie beneath the surface of the ground. The water in these rocks is by capillarity made to form an inclined plane towards the sea, which at the point referred to has its surface at sixty feet above mean sea-level. The water-plane was shown to be in a state exceedingly sensitive to the following influences: namely, *atmospheric pressure, lunar attraction*, and *solar attraction.*

In order to determine the relative extent of these and other disturbing influences upon the water-plane, an artesian well was sunk in the Triassic rocks to a point below mean sea-level, and the rise and fall of the column of water sixty feet in height, freed from the friction in the rock, was used as the means of registering those disturbances in the water-plane, by using a mechanical contrivance of a float and drum, caused to revolve by clockwork, to trace a curve upon the diagram paper.

The curve showed the extent from moment to moment of the atmospheric variations, and also the effects of the attraction of the sun and moon upon the water-plane in producing oscillations in the first case and true semi-diurnal lunar and solar tides in the latter case.

The effect of the rainfall was also shown on the diagram.

It was also shown that there were periods when all the forces which have been named were in equilibrium, the water-plane remaining in a state of perfect quiescence during those periods.

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11. *On the Physical Theory of the Tides, with especial reference to their Diurnal Inequality. By the* Rev. JAMES PEARSON, *M.A., F.R.A.S.*

The author commenced by explaining the great interest he had taken in the subject for twelve years past, and his confidence in the process which had attended his

method of treating it. This method was an extension of that made familiar to us in the writings of Sir John Lubbock and used by Dr. Whewell. Their system, however, was imperfect, inasmuch as it did not introduce what was most necessary, viz., a fourfold classification of the tides, as follows: 1, a lunar direct tide; 2, a lunar obverse tide; 3, a solar direct tide; and 4, a solar obverse tide. The author claimed to have shown that this classification, inasmuch as it introduced the consideration of the difference between the lunar action, direct or obverse, when in the *southern* hemisphere, as contrasted with the corresponding action when in the *northern* hemisphere, gave a clue to the *law* of the diurnal inequality, and when the effects were formulated in a series of tables the heights of successive tides could be predicted with unprecedented accuracy. The author explained how he had been helped in finding out this law of the inequality by means of a graphic process, which exhibited the varying positions of the sun and moon, drawn to scale, and the resulting heights of lunar and solar, direct and obverse, tides; and he disclaimed any opposition in his method of treating the subject to the more extensive theory favoured by the British Association; suggesting only that, as his (the author's) observations were confined to Liverpool and the west coast of Lancashire, an effort should be made to carry out a system of observations in other parts of Great Britain. He regretted that this effort should languish for want of funds, which ought to be forthcoming to the needful amount from the Association, since amateurs were left to do so much at their own private expense.

The author then described his self-registering instrument, which had been kindly placed in a suitable position by the harbour authorities at Fleetwood, the whole constituting a suitable tidal observatory, and the registers were compared month by month with those obtained at George's Pier, Liverpool. The paper concluded by stating that the system of tables thus originated had been adopted by the authorities of the Hydrographic Department of the Admiralty for the last six years, for Liverpool only, and had been inserted in the annual volume of Tide Tables published by their authority.

SATURDAY, SEPTEMBER 22.

The following Report and Papers were read:—

1. *Report of the Committee on Mathematical Tables.*—See Reports, p. 118.

2. *On Lamé's Differential Equation. By* Professor LINDEMANN.—See Reports, p. 351.

3. *On a Fundamental Theorem in the Dynamics of Non-Euclidian Space. By* Professor ROBERT S. BALL, *LL.D., F.R.S.*

The theorem contained in this paper has been familiar to the author for two or three years. He had always thought hitherto that it must have been known to mathematicians, as it seems to be of fundamental importance in elliptic space. It is true that he never could find any reference to it, but he had been disposed to attribute this to his ignorance of the literature of the subject. Professor Lindemann, who has done so much for this theory, had, however, assured him that the theorem is new.

The effect produced on a rigid system by a pair of equal rotations about two right lines which are conjugate polars to the absolute is called by Clifford a *right vector*. If the rotations are equal, but with opposite signs, they constitute a *left vector*. A pair of equal forces on two conjugate polars we may call a *right couple*, or a *left couple*, according to the way in which the forces are directed.

The theorem now submitted is thus stated: The virtual moment between any right vector and any left couple, or between any left vector and any right couple, is equal to zero.

4. *On a Geometrical Illustration of a Dynamical Problem.* *By* Professor Robert S. Ball, *LL.D., F.R.S.*

A rigid system, with freedom of the second order, is able to make small twists about a singly infinite number of screws. If each screw be represented by a point, then—

(1) All the points lie on a circle.

(2) The angle between two screws equals the angle subtended at the circumference by their corresponding points.

(3) The pitch of each screw equals the distance of its point from a ray.

(4) Two reciprocal screws correspond to the extremities of a chord through the pole of the ray.

(5) The impulsive screws and instantaneous screws correspond to the homographic systems of points.

(6) The directive axis of the homography passes through the pole of the ray.

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5. *On an Approximate Expression for x!* *By* Professor A. R. Forsyth.

By a well-known formula we have

$$\log x! = \log \sqrt{2\pi} + (x+\tfrac{1}{2}) \log x - x + \frac{B_1}{1\,.\,2x} - \frac{B_3}{3\,.\,4\,.\,x^3} + \ldots$$

$B_1, B_3, \ldots$ being Bernouilli's numbers, and their values being given by

$$B_1 = \tfrac{1}{6}, \qquad B_3 = \tfrac{1}{30}, \qquad B_5 = \tfrac{1}{42} \ldots$$

so that for large values of x we have approximately

$$x! = \sqrt{2\pi x}\ x^x \epsilon^{-x},$$

the error being of the order $\dfrac{1}{12x}$ of the product.

But an expression somewhat more accurate, and by no means complicated in form, can be obtained from the above. It is easy to verify that

$$\log x = \log (x+\mu) - \frac{\mu}{x} + \tfrac{1}{2}\frac{\mu^2}{x^2} - \tfrac{1}{3}\frac{\mu^3}{x^3} + \ldots$$

being any quantity less than x: so that we easily obtain

$$\log x! = \log \sqrt{2\pi} + (x+\tfrac{1}{2}) \log (x+\mu) - (x+\mu)$$
$$+ \frac{1}{1\,.\,2\,.\,x}(\mu^2 - \mu + B_1) - \frac{1}{x^2}\left(\frac{\mu^3}{3} - \frac{\mu^2}{4}\right)$$
$$+ \frac{1}{x^3}\left(\frac{\mu^4}{4} - \frac{\mu^3}{6} - \frac{B_3}{12}\right) + \ldots$$

Choose μ, which is as yet arbitrary, so as to satisfy

$$\mu^2 - \mu + B_1 = 0,$$

so that if μ_1, μ_2 be the two values

$$\mu_1 + \mu_2 = 1, \qquad \mu_1\mu_2 = B_1 = \tfrac{1}{6}.$$

Substitute μ_1 and μ_2 in succession in the above series; add the corresponding sides together and divide by 2. The expressions on the right-hand side are symmetric functions of μ_1 and μ_2, and can therefore be written down free from all surds. Now μ has been so chosen as to remove the term in $\dfrac{1}{x}$; and it happens that these values of μ, which are sufficient for the purpose, make the coefficient of $\dfrac{1}{x^2}$ zero

so that the first term in the series which enters is of the order $\frac{1}{x^3}$. In fact, we have after some easy reductions

$$\log x! = \log \sqrt{2\pi} + \tfrac{1}{2}(x+\tfrac{1}{2}) \log (x^2+x+\tfrac{1}{6}) - (x+\tfrac{1}{2})$$
$$+ \frac{1}{240x^3} - \frac{1}{160x^4} + \frac{253}{45360x^5} - \ldots$$

and therefore when we write

$$x! = \sqrt{2\pi}\left\{\frac{\sqrt{x^2+x+\frac{1}{6}}}{e}\right\}^{x+\frac{1}{2}}$$

the error is less than $\frac{1}{240x^3}$ of the whole, *i.e.* less than $\frac{1}{20x^2}$ of the error in adopting the ordinary expression.

6. *On a Generalised Hypergeometric Series.*[1] *By* Professor A. R. Forsyth.

The object of the communication was to deduce for the series

$$1 + \frac{\alpha\beta\theta}{\gamma\epsilon}x + \frac{\alpha . \alpha+1 . \beta . \beta+1 . \theta . \theta+1}{1 . 2 . \gamma . \gamma+1 . \epsilon . \epsilon+1}x^2 + \ldots$$

the relations corresponding to those which hold for Gauss's series as they occur in the memoirs of Gauss ('Ges. Werke,' bd. iii.) and Kummer ('Crelle,' t. xv.)

7. *Note on a Simple Method of Solving the General Equation of the Fourth Degree. By* Alfred Lodge.

If in the $=^n (a_0, a_1, a_2, a_3, a_4)(x, 1)^4 = 0$, the substitution $y = a_0x + a_1$ be made, the resulting $=^n$ is of the form

$$y^4 + 6Hy^2 + 4Gy + F = 0 \quad . \quad . \quad . \quad . \quad (1),$$

which can be arranged as the difference of two squares, viz.

$$(y^2 + 3H + 2q^2)^2 - \left(2qy - \frac{G}{q}\right)^2 = 0 \quad . \quad . \quad . \quad (2),$$

by introducing a quantity q, which only occurs in the absolute term of the equation and is determined by the cubic equation in q^2,

$$4q^6 + 12Hq^4 + (9H^2 - F)q^2 - G^2 = 0 \quad . \quad . \quad . \quad (3),$$

If, then, we can obtain one root of this cubic (and there is always at least one *positive* root), the solution of the biquadratic is complete.

By substituting $a_0\phi = q^2 + H$, the cubic can be reduced to the form

$$4\phi^3 - I\phi + J = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (4),$$

where

$$I(\equiv a_0a_4 - 4a_1a_3 + 3a_2^2),$$

and

$$J\left(\equiv \begin{vmatrix} a_0, & a_1, & a_2 \\ a_1, & a_2, & a_3 \\ a_2, & a_3, & a_4 \end{vmatrix}\right)$$

are the two invariants of the original biquadratic, whose invariance gives us

$$a_0^2I = F + 3H^2, \text{ and } a_0^3J = a_0^2HI - G^2 - 4H^3.$$

[It may be noticed as an interesting fact that each term of these expressions involves the coefficients of the original equation to an *order* equal to the *weight*.]

[1] Published *in extenso* in the *Quarterly Journal of Mathematics*, vol. xix. pp. 292–337.

The solution of (4) resolves itself into one of three forms, according as (first) I^3-27J^2 is positive, in which case all the roots are real; (secondly) I^3-27J^2 is negative, but I is still positive; or (thirdly) I^3-27J^2 is negative, and I is negative—in each of which latter cases there is only one real root.

In the first case we have the well-known solution of the cubic by comparing it with the trigonometrical identity

$$4\cos^3 a - 3\cos a - \cos 3a \equiv 0.$$

In the second case it can be solved by comparison with the identity

$$4\cosh^3 a - 3\cosh a - \cosh 3a \equiv 0;$$

and in the third by comparison with

$$4\sinh^3 a + 3\sinh a - \sinh 3a \equiv 0.$$

[These identities are apparent at once on using their exponential values.]

First then, when I^3-27J^2 is positive, we have

$$x = n\cos a, \text{ where } \cos 3a = \sqrt{\frac{27J^2}{I^3}};$$

secondly, when I^3-27J^2 is negative, but I is positive,

$$x = n\cosh a, \text{ where } \cosh 3a = \sqrt{\frac{27J^2}{I^3}};$$

thirdly, when I is negative,

$$x = n\sinh a, \text{ where } \sinh 3a = \sqrt{\frac{27J}{-I^3}};$$

in each case n being numerically equal to $\sqrt{\frac{I}{3}}$ and of opposite sign to J.

It seems worthy of notice that, since the two quadratic factors into which the biquadratic can be split [see equation (2)] differ only in the sign of q, the biquadratic is equivalent to a single quadratic equation—

$$y^2+2qy+2q^2+3H-\frac{G}{q}=0 \quad . \quad . \quad . \quad . \quad (5),$$

in which q may have any one of six values—namely, any one of the roots of the cubic in q^2. The six different forms of (5) are, of course, the six different combinations-in-pairs of the linear factors of the biquadratic. It is easy to see from this the intimate association of equal and zero roots in the cubic with equal roots in the biquadratic; for if two of the roots of the biquadratic are equal, we can only form four different quadratic expressions (5), and hence two roots of the cubic must be equal. Again, if the biquadratic has two pairs of equal roots, the two equal roots of the cubic must be zero, since only three combinations can be made: and so on.

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8. *On Symmetric Functions, and in particular on certain Inverse Operators in connection therewith.*[1] *By* Captain P. A. MacMahon, *R.A.*

This paper is more particularly concerned with non-unitary symmetric functions, on account of the author's recent discovery that they are in fact seminvariants of an allied quantic. Some recent theorems in seminvariants are herein applied to the calculation of symmetric functions.

§ 1. The equation considered is in every case

$$x^n - a_1x^{n-1} + a_2x^{n-2} - a_3x^{n-3} + \; . \; . \; . \; . \; . \; = 0;$$

and if partitions in (   ) refer to this equation, and those in ((   )) to the equation

$$x^n - a_2x^{n-1} + a_3x^{n-2} - a_4x^{n-3} + \; . \; . \; . \; . \; . \; = 0,$$

[1] Published *in extenso* in the *Proceedings of the London Mathematical Society.*

it is shown that $a_1^{\lambda-\mu}((\mu^m.\gamma^n. \quad ...))$ represents the terms of highest degree in symmetric function $(\lambda.\mu^m.\gamma^n. \ldots .)$; so that every known symmetric function gives rise to the terms of highest degree in an infinite number of higher symmetric functions, by simply making a unit-increase of suffixes throughout (a_0 having been introduced for the sake of homogeneity) and introducing a factor a_1 raised to the necessary power.

A simplification in the performance of Mr. Hammond's operator d_λ is thence derived.

§ 2. It is shown, from analogy with the theory of seminvariants, that the non-unitary portion of a symmetric function may be separately calculated, and its complete expression thence derived from a series of functions corresponding to the coefficients of Prof. Cayley's generalised canonical form of quantics.

§ 3. Beginning with Mr. Hammond's operators, defined by the equation

$$d_\lambda = \frac{d}{da_\lambda} + a_1 \frac{d}{da_{\lambda+1}} + a_2 \frac{d}{da_{\lambda+2}} + \ldots\ldots$$

the following formula is proved, viz.

$$\frac{d}{da_\lambda} = d_\lambda - H_{(1)}d_{\lambda+1} + H_{(2)}d_{\lambda+2} - \ldots\ldots + (-)^r H_{(r)}d_{\lambda+r} + \ldots$$

wherein $H_{(r)}$ represents the sum of the homogeneous symmetric functions of weight r.

This formula is applied to the calculation of symmetric functions, and various properties of the function $H_{(r)}$ are developed; in particular it is proved that the general term in $H_{(r)}$ is

$$(-)^{r+k} \frac{k!}{a_1!\, a_2!\, a_3! \ldots} a_1^{a_1} a_2^{a_2} a_3^{a_3} \ldots$$

k being the degree of the term, which gives rise to the following curious theorem, viz.: If in the expression of S_n we multiply each term by the degree of the term, and then divide the whole expression by the degree of the expression, we obtain $H_{(n)}$, and conversely.

§ 4. The following inverse operators are obtained, viz.:—

$$V_{-1} = a_1 \frac{d}{da_0} + 2a_2 \frac{d}{da_1} + 3a_3 \frac{d}{da_2} + \ldots$$
$$= S_1 d_0 - S_2 d_1 + S_3 d_2 - S_4 d_3 + \ldots + (-)^r S_{r+1} d_r + \ldots$$

$$V_{-r} = (r)\frac{d}{da_0} + (r1)\frac{d}{da_1} + (r1^2)\frac{d}{da_2} + \ldots + (r1^s)\frac{d}{da^s} + \ldots$$
$$= S_r d_0 - S_{r+1} d_1 + S_{r+2} d_2 - \ldots + (-)^3{}_s S_{r+s} d_s + \ldots$$

and it is proved that

$$V_{-r}(\lambda^l) = \lambda(\lambda^l r)\,;\; r \not\equiv \lambda.$$
$$V_{-\lambda}(\lambda^l) = (l+1)\lambda(\lambda^{l+1}).$$

The effect of the operator on certain other functions is considered.

§ 5. The definition of $H_{(\lambda)}$ is extended, so that the function $H_{(\lambda^l)}$ has a definite meaning, and it is shown that $H_{(\lambda^l)}$ bears the same relation to symmetric function (λ^l) that $H_{(\lambda)}$ bears to (λ), and is derivable from it in the same manner, viz. by means of the theorem given *ante*.

A method is given for calculating $S_{\overline{w.j}}$ where $S_{\overline{w.j}}$ represents the sum of all the homogeneous symmetric functions of weight w and of degree j at most.

§ 6. Representing the expression

$$H_{(t)}(\lambda.\mu.r\ldots) - H_{(t-1)}(\lambda.\mu.r\ldots 1) + H_{(t-2)}(\lambda.\mu.r\ldots 1^2) - \ldots$$
$$+ (-)^3_s H_{(t-s)}(\lambda.\mu.r\ldots 1^s) + \ldots + (-)^t(\lambda.\mu.r\ldots 1^t)$$

by $F\{(t).(\lambda.\mu.r\ldots)\}$, the function F is examined, it being first proved that it is in every case a non-unitary symmetric function; numerous relations are deduced, and in particular an expression is obtained for the sum of all the non-unitary symmetric functions of a given weight; this is found to be

$$\sum_{s=w}^{s=2}(-)^s H_{(w-s)}\{(2.1^{s-2})+(2^2.1^{s-4})+(2^3.1^{s-6})+\ldots+(2^{\frac{1}{2}s}) \text{ or } (2^{\frac{1}{2}(s-1)}1)\}.$$

Also the sum of the non-unitary symmetric functions of weight w, which contains no part less than j, is

$$\sum_{i=k}^{i=1}[H_{(w-ij)}\{(j^i)+(-)^{ij-j}(j1^{ij-j})\}-H_{(w-ij-1)}\{(j^i1)+(-)^{ij-j}(j1^{ij-j+1})\}$$
$$+H^{(w-ij-2)}\{(j^i1^2)+(-)^{ij-j}(j1^{ij-j+2})\}-\ldots],$$

where k is the integral part of $\frac{w}{j}$, and the terms are continued up to and including the term containing H_0.

§ 7. The expressions in terms of the coefficients of the non-unitary symmetric functions, or, as they may be otherwise called, the single partition seminvariants, of weight thirteen, are given in a table.

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9. *On the most Commodious and Comprehensive Calculus.*
By Dr. Ernst Schröder.

The calculus of the four algebraical operations—viz., addition, multiplication, and converse—does not imply the greatest abundance of formal laws and consequences. Accepting symbolically the notation $a+b$ for a certain function $f\ (a, b)$ of two variables, and $a.b$ or ab for another function $\phi\ (a, b)$, a calculus is found out to be the most comprehensive one that enjoys the following properties.

Both functions are throughout one-valued (= determinative) and invertible; they are commutative and associative, like the proper addition and multiplication; besides, they submit to the law, that whenever $a+b=c$, then also $b+c=a$ and $c+a=b$; again, when $a.b=c$, then also $b.c=a$, and $c.a=b$, so that every term or factor may also be transferred as such to the other side (member) of any equation.

None of the distributive principles, as $a.(b+c)=a.b+a.c$, holds good between the aforesaid operations, but instead of these we have the still simpler and ampler law expressed by the formulæ

$$(a+b).c=(b+c).a=(c+a).b=c+ab=b+ca=a+bc.$$

Brackets in this calculus are therefore obliterated by simply cancelling them, which yields the most commodious imaginable way of developing products of polynomials. Moreover, in a series of operations it is allowed to confound any two signs of addition and of multiplication.

Lastly (the formulæ

$$a+0=a, \qquad a.1=a$$
$$a+a=0, \qquad a.a=1$$

proving generally valid), the solution of an equation is most easily performed, whenever possible.

It is not difficult to explain the functions f and ϕ for the whole dominion of ordinary complex numbers, both proving generally discontinuous. First explain them for a province of but two numbers, say 0 and 1, by means of the tables

$$\left.\begin{array}{l}0=0+0=1+1\\1=1+0=0+1\end{array}\right\} \qquad \left\{\begin{array}{l}0=0.1=1.0\\1=1.1=0.0\end{array}\right.$$

then extend their definition unto the province of the real numbers, supposing each to be *expressed in the binary scale* (the negative numbers as 'arithmetical complements' with an infinity of 1's preceding).

Then $a+b$ and $a.b$ ought but to represent the results of combining together the homologous digits of a and b according to these tables.

In order to avoid the particular fact that $a+b$ would coincide with minus ab, let the positive part of the axis of the real numbers be reflected into itself according to any principle whatever, but such that the point 0 would correspond to itself. Do then the same with the negative part, but according to any other principle. Then the substitutes will evidently bear the same formal relations to each other as the original numbers, provided, of course, that we now define ab as the point or number representative of the symbolical product, heretofore described, of those numbers whose representatives are a and b (and so on).

Finally, the explanations may be extended to the ordinary complex numbers

$$a+b\times\sqrt{-1}$$

by simply combining together their real parts, and again the real coefficients of the imaginary parts, according to the rules given.

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10. *Exposition of a Logical Principle, as disclosed by the Algebra of Logic, but overlooked by the Ancient Logicians.* *By* Dr. Ernst Schröder.

The algebra of logic being the concisest expression of the 'laws of thought' in the Boolean sense, enables us to discover gaps in the ancient system.

By the method of Ch. Peirce the law of distribution

$$a(b+c)=ab+ac$$

is capable of being demonstrated through syllogisms, but merely as an *implication in the one sense*, viz., it can be shown that $a(b+c)$ *implies* $ab+ac$.

The opposite implication has in a similar way never been proved, and the impossibility of this proof being ever given may be demonstrated by means of a certain 'calculus with algorithms or calculusses,' the notion of which is to be founded on the foregoing communication.

This implication, therefore, is to be considered as an independent axiom of thought or logical principle.

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11. *On Curves of the Fourth Class, with a Triple and a Single Focus.* *By* Henry M. Jeffery, *F.R.S.*

1. These ovals may be either singular or non-singular. They may be smooth, or have excrescences called stapetes, characterised by two cusps and a crunode.

Let P, Q denote the triple and single forms of such a quartic; R, S the single foci of its satellite-conic; p, q, r, s the perpendiculars drawn from them on any tangent. All such quartics have the property

$$\kappa p^3q=rs+\lambda.$$

Their equation, when referred to two-line tangential co-ordinates, is

$$0=-\kappa(1+d\xi)+m\xi+n\eta-1)(p\xi+q\eta-1)(\xi^2+\eta^2)+\lambda(\xi^2+\eta^2)^2\equiv\phi.$$

Singular quartics are discriminated by a subsidiary curve (D_1), which exhibits the mutual relation between the parameters κ and λ, when

$$\frac{d\phi}{d\xi}=0,\quad\frac{d\phi}{d\eta}=0.$$

A diagram exhibiting this curve is a chart of 'deficiency.'

Stapete-points, which are the dual forms of points of undulation, are discriminated by a second curve (D_2), the locus of (κ, λ), when

$$\frac{d^2\eta}{d\xi^2}=0, \quad \frac{d^3\eta}{d\xi^3}=0.$$

2. To determine curve (D_1) when the quartics are bitangential.

If the tests of singularity be applied to the quartic (ϕ),

$$\kappa(1+d\xi)=u_1v_1(\xi^2+\eta^2)+\lambda(\xi^2+\eta^2)^2$$

$$\kappa d=2\xi u_1v_1+[2mp\xi+(np+mq)\eta-(p+m)]\,(\xi^2+\eta^2)+4\lambda\xi(\xi^2+\eta^2)$$

$$\text{(A)} \qquad 0=2\eta u_1v_1+[2nq\eta+(np+mq)\xi-(q+n)]\,(\xi^2+\eta^2)+4\lambda\eta(\xi^2+\eta^2)$$

$$\text{(B)} \quad \kappa(4+3d\xi)=[2-(m+p)\xi-(n+q)\eta]\,(\xi^2+\eta^2)$$

By eliminating κ and λ, it appears that all the bitangents must touch the parabolic cubic

$$\text{(C)} \qquad d\eta\{(m+p)\xi+(n+q)\eta-2\}=$$
$$(4+3d\xi)\{(np+mq)(\xi^2-\eta^2)-2(mp-nq)\xi\eta+(m+p)\eta-(n+q)\xi\}$$

If ξ, η be eliminated from (A), (B), (C), the eliminant is the required curve (D_1) referred to κ, λ as ordinates.

The curve (D_1) is conveniently drawn by points, after drawing (C) by line –, or point –, co-ordinates: to each line or point in (C) a single value of λ and κ corresponds in (A) and (B).

The curve (D_1) has five asymptotes.

To the values

$\xi=\pm\eta=\infty$ there correspond $\kappa=\infty$, $4\lambda+mp\pm 2np\pm 2mq+3nq=0$.

$\xi=\ \ \eta=0 \qquad \lambda=\infty,\ \kappa=0.$

$\eta=\infty,\ d(n+q)+(4+3d\xi)\,(np+mq)=0, \qquad \kappa=\infty,\ \lambda+nq=0.$

$\eta=0,\ 4+3d\xi=0$ corresponds $\kappa(1+d\xi)=(m\xi-1)\,(p\xi-1)\xi^2+\lambda\xi^4$.

3. In order to obtain all possible varieties of curve (D_1), the five cases of the cubic (C) must be examined. When S, the quartic, and T, the sextic, invariants of (C) have been found, the conditions are known for a nodal cubic $(T^2=64S^3)$, and for a cusped cubic $(S=0,\ T=0)$. For slight alterations in the constants near these critical values the non-singular companion-cubics may be obtained.

If two of the foci P, Q, R, S coincide, this cubic (C) degenerates into a conic and point. If R, S be at infinity, the line at infinity is a bitangent.

4. To determine curve (D_2) when the quartics of this group have stapete-points.

If the equations to the quartic $(\phi=0)$ be differentiated thrice, and the conditions introduced for a stapete-point

$$\left(\frac{d^2\eta}{d\xi^2}=0, \quad \frac{d^3\eta}{d\xi^3}=0\right),$$

the elimination of κ, λ gives the following equations: $\left(t=\dfrac{d\eta}{d\xi}\right)$

$$\{\tfrac{1}{2}(\xi^2+\eta^2)\,(1+t^2)-(\xi+\eta t)^2\}\,\{(m+nt)\,(p\xi+q\eta-1)+(p+qt)\,(m\xi+n\eta-1)\}$$
$$=(m\xi+n\eta-1)\,(p\xi+q\eta-1)\,(\xi+\eta t)\,(1+t^2)$$
$$-\frac{2}{1+t^2}(m+nt)\,(p+qt)\,(\xi+\eta t)^3 \quad . \quad . \quad \text{(A)}$$

$$\frac{4}{d}(1+d\xi)\,(\xi+\eta t)\,\{(\xi^2+\eta^2)(1+t^2)-2(\xi+\eta t)^2\}$$
$$=(1+t^2)\,(\xi^2+\eta^2)^2-4(\xi^2+\eta^2)\,(\xi+\eta t)^2 \quad . \quad . \quad . \quad . \quad \text{(B)}$$

If successive values be given to t from $+\infty$ to $-\infty$, the corresponding cubics and quartics may be drawn from (A) and (B); their combinations determine the twelve values of ξ, η, real or imaginary.

Or the ratio $\xi : \eta$ may be thus obtained without drawing.

Write (A) and (B) in the order of their homogeneous terms:

$$u_3 + u_2 + u_1 = 0, \qquad v_4 + v_3 = 0.$$

Their eliminant is of the ninth order, homogeneous in $\xi : \eta$:

$$v_4^2 u_1 - v_4 v_3 u_2 + v_3^2 u_3 = 0.$$

By giving successive values to $t\left(=\frac{d\eta}{d\xi}\right)$, the nine values of $\frac{\xi}{\eta}$ may be found in each case, and by aid of (A) or (B) the separate values of ξ, η.

Linear expressions were found for κ, λ by the original differentiations of ϕ in terms of ξ, η, $\frac{d\eta}{d\xi}$; when the several values of these last variables are substituted, κ, λ can be obtained correctly.

5. By this method the curve (D_2) has been drawn when $p=q=0$, *i.e.* for the duals of bicircular quartics, and was exhibited.

In this case the curve (A) becomes a quadric, and the homogeneous equation in $\xi : \eta$ is reduced to a quartic, which may have four or two real values.

MONDAY, SEPTEMBER 24.

The following Reports and Papers were read:—

1. *Sixteenth Report of the Committee on Underground Temperature.*— See Reports, p. 45.

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2. *Report of the Committee appointed to co-operate with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.*—See Reports, p. 125.

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3. *On the Completion of the European Portion of the Preliminary Meteorological Catalogue. By* G. J. SYMONS, *F.R.S.*

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4. *On the Heat of the Sunshine at the Kew Observatory, as registered by Campbell's method. By* Professors H. E. ROSCOE, *F.R.S., and* BALFOUR STEWART, *F.R.S.*

On June 10, 1875, we communicated to the Royal Society a paper containing the observations of the heat of sunshine made by Campbell's method during the 24 years 1855 to 1874, and we now communicate to the British Association a second series of such observations made between 1875 and 1882.

The following extract from a Parliamentary Report will explain the process adopted by Mr. Campbell:—

'A hemispherical cavity is made in a block of wood, and a spherical lens is placed in this cavity in such a position that while its centre coincides with the centre of the cavity its chief focus is at some point of the hemispherical concave surface, the exact point being of course determined by the direction in which the rays strike the lens.

'Whenever, therefore, the sun shines, a portion of the wood will be carbonised

or burnt out by his concentrated beams; and inasmuch as the sun continually changes his position, not only from hour to hour, but from day to day, it follows that different portions of the wood will be acted upon, not only from one hour to another, but also from one day to another.'

The blocks are all of mahogany, being, as nearly as possible, of the same quality; and the diameter of the sphere is about $5\frac{1}{4}$ inches.

All the blocks have been treated by us in the same way. The hollows burnt out have been filled with a mixture of bees' wax and olive oil of such a consistency that we could easily work it into the burnt cavities until the whole internal hemisphere should be made to present the same smooth surface which it had before it was burnt. A comparison of the weight of the (previously saturated) block before and after the process was supposed to give us a good estimation of the extent of the hollows. The mean of two such determinations was taken, and the near concordance of the two will show that the results are as accurate as the nature of the experiment requires.

As the wax used for the second series was not necessarily the same as that used for the first, we caused six bowls of the first series to be refilled with the second series wax and weighed, by which means we obtained the coefficient necessary to reduce the second series to the same standard as the first.

There still, however, remains the fact that the first series were made at the Board of Health (now the Local Government Board), at Richmond Terrace, Whitehall, while the second were made at the Kew Observatory.

The last bowl treated in the old series was that ending December 1874, and the first of the new series, that ending June 1875, is defective, owing to the shadow of a post falling on it. We have, therefore, rejected it from our list. Mr. Shaw, student at Owens College, was good enough to assist us in the determinations of the Kew set. The specific gravity of the mixture of wax and oil used for this set was, at 74° C., 0·838, and the melting point was 61·5° C.

In the following table we have the results obtained:—

TABLE I.—WEIGHT OF MIXTURE FILLING THE HOLLOWS OF THE KEW BOWLS.

	Date	First Experiment	Second Experiment	Mean
I.	June 24, 1875, to Dec. 22, 1875 . .	24·4	24·4	24·4
II.	Dec. 21, 1875, to June 23, 1876 . .	33·0	33·8	33·4
III.*	June 22, 1876, to Feb. 2, 1877 . .	39·0	39·2	39·1
IV.*	Feb. 2, 1877, to June 21, 1877 . .	16·6	16·2	16·4
V.	June 21, 1877, to Dec. 21, 1877 . .	26·8	27·8	27·3
VI.	Dec. 21, 1877, to June 21, 1878 . .	19·9	19·8	19·8
VII.	June 21, 1878, to Dec. 21, 1878 . .	25·6	26·2	25·9
VIII.	Dec. 21, 1878, to June 21, 1879 . .	22·4	22·1	22·3
IX.	June 21, 1879, to Dec. 21, 1879 . .	18·6	18·2	18·4
X.	Dec. 21, 1879, to June 21, 1880 . .	21·2	20·5	20·8
XI.	June 21, 1880, to Dec. 21, 1880 . .	13·3	12·9	13·1
XII.	Dec. 21, 1880, to June 21, 1881 . .	13·3	13·6	13·5
XIII.	June 21, 1881, to Dec. 21, 1881 . .	35·3	35·5	35·4
XIV.	Dec. 21, 1881, to June 21, 1882 . .	24·1	24·2	24·2
XV.	June 21, 1882, to Dec. 21, 1882 . .	28·8	28·2	28·5

It will be seen from this table that the change of bowls was always made as nearly as possible at the solstice, with the exception of two occasions—viz. No. III., where the bowl was inadvertently allowed to remain from June 22, 1876, to February 2, 1877, and No. IV., where the observation was made from February 2, 1877, to the ensuing solstice. Thus No. III. embraces a larger and No. IV. a smaller interval than usual.

We are afraid that No. III. must be rejected, as the image of the sun must have travelled twice over part of the wood, and we do not know how to correct for this. With regard to No. IV., it will perhaps be sufficient to increase it propor-

tionally, so as to embrace the proper time-interval, in which case the recorded result, 16·4, would be changed into 20·4.

Let us next compare the mean heating effect of the sun for the half-year preceding the summer solstice with that for the half-year preceding the winter solstice.

TABLE II.—COMPARING THE SUN'S HEATING POWER FOR THE TWO HALVES OF THE YEAR.

—	Half-year Ending Summer Solstice	Half-year Ending Winter Solstice
I.	—	24·4
II.	33·4	—
IV. (corrected)	20·4	—
V.	—	27·3
VI.	19·8	—
VII.	—	25·9
VIII.	22·3	—
IX.	—	18·4
X.	20·8	—
XI.	—	13·1
XII.	13·5	—
XIII.	—	35·4
XIV.	24·2	—
XV.	—	28·5
Sum of seven .	154·4	173·0

It will be seen from this that, as in the former series, there is more heat of sunshine during the half-year after than during the half-year before the summer solstice. This difference is not, however, so marked as in the previous series, where the numbers were 184·17 and 353·68. Whether the change of locality will account for this, the immediate vicinity of a large city exaggerating the difference, or whether the observations are not sufficiently numerous to eliminate peculiarities of seasons, we cannot tell.

As in the previous series it will be necessary to form our observations into yearly values; this is done in the following table:—

TABLE III.—YEARLY VALUES OF THE HEAT OF SUNSHINE AT KEW.

Mean Date	Amount	Mean Date	Amount
December 1875 . .	57·8	June 1879 . . .	40·7
June 1876 . . .	—	December 1879 . .	39·2
December 1876 . .	—	June 1880 . . .	33·9
June 1877 . . .	47·7	December 1880 . .	26·6
December 1877 . .	47·1	June 1881 . . .	48·9
June 1878 . . .	45·7	December 1881 . .	59·6
December 1878 . .	48·2	June 1882 . . .	52·7

With reference to this table we may permit ourselves to remark that we may regard the numbers for 1877–1880 as belonging to a period of few sun-spots, while the last three observations may be regarded as belonging to a period of an increasing amount of spots. On the whole the results are in accordance with those of the previous series, in which large numbers were found to be associated with times of maximum sun-spots and small numbers with times of minimum.

It will be found that the mean of the yearly values of the above table is 45·67.

In order to make allowance for difference of wax six of the former bowls were treated with the new wax, and the following results were obtained:—

TABLE IV.—COMPARISON OF THE TWO TREATMENTS WITH WAX.

Date	New Wax	Old Wax
December 1871 to June 1872	4·65	5·170
June 1872 to December 1872	12·55	14·505
December 1872 to June 1873	3·35	3·653
June 1873 to December 1873	23·65	25·538
December 1873 to June 1874	6·95	8·905
June 1874 to December 1874	18·15	20·573
Total	69·30	78·344

These results are sufficiently consistent to assure us that we cannot go far wrong if we multiply the new results by the factor $\frac{78·344}{69·30} = 1·13$ in order to render them comparable to those of the old as far as treatment is concerned.

If we perform this operation we shall find that the mean yearly value for the Kew series becomes 51·607, while the mean yearly value of the old series was only 30·468.

If we may suppose that this difference represents the effect of change of locality, and that the second series is large enough to divest a comparison between the two from the influence of seasonal peculiarities, then we may conclude that the Kew series, corrected for wax, has to be multiplied by the factor $\frac{30·468}{51·607} = 0·59$ in order to reduce it to London value. In the following table we have given the London and the Kew yearly values, in the first column of which the Kew values are merely corrected for difference of treatment, while in the second it has been attempted to correct them for change of locality.

TABLE V.—YEARLY VALUES OF HEAT OF SUNSHINE.

Date	Place	Value	Value reduced to London Standard	Date	Place	Value	Value reduced to London Standard
June 1858	London	—	42·44	Dec. 1870	London	—	37·68
Dec. 1858	„	—	43·61	June 1871	„	—	32·47
June 1859	„	—	51·52	Dec. 1871	„	—	21·95
Dec. 1859	„	—	43·86	June 1872	„	—	19·68
June 1860	„	—	32·42	Dec. 1872	„	—	18·16
Dec. 1860	„	—	29·83	June 1873	„	—	29·19
June 1861	„	—	27·37	Dec. 1873	„	—	34·44
Dec. 1861	„	—	25·60	June 1874	„	—	29·48
June 1862	„	—	29·51	Dec. 1874	—	—	—
Dec. 1862	„	—	26·79	June 1875	—	—	—
June 1863	„	—	30·11	Dec. 1875	Kew	65·31	38·53
Dec. 1863	„	—	28·33	June 1876	„	—	—
June 1864	„	—	19·26	Dec. 1876	„	—	—
Dec. 1864	„	—	25·21	June 1877	„	53·90	31·80
June 1865	„	—	28·11	Dec. 1877	„	53·22	31·40
Dec. 1865	„	—	24·83	June 1878	„	51·64	30·47
June 1866	„	—	25·79	Dec. 1878	„	54·47	32·14
Dec. 1866	„	—	28·79	June 1879	„	45·99	27·13
June 1867	„	—	33·24	Dec. 1879	„	44·30	26·14
Dec. 1867	„	—	38·90	June 1880	„	38·31	22·60
June 1868	„	—	20·19	Dec. 1880	„	30·06	17·73
Dec. 1868	„	—	20·52	June 1881	„	55·26	32·60
June 1869	„	—	31·21	Dec. 1881	„	67·35	39·74
Dec. 1869	„	—	34·19	June 1882	„	59·55	35·13
June 1870	„	—	31·75				

It will be seen that in the above table we have results during two sun-spot cycles nearly. If we divide (as has been done for the heights of rivers) the interval between each solar maximum, without regard of its exact length, into twelve equal parts, our data will give us values corresponding to two such sets of twelve. If we further smooth our values by taking means of three, and if we take the means of the two sets of twelve, we obtain finally one set of twelve values, which will, perhaps, afford us a rough indication whether there is really a connection between heat of sunshine, as herein determined, and sun-spot frequency, and whether, as in the case of rivers, there are traces of a double terrestrial period for one of sun-spots.

We thus obtain—

Table VI.—Showing the Sun's Heating Power, corresponding to the Various Phases of Sun-spot Frequency. (0) *Denotes Maximum Sun-spots.*

(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
38·57	30·28	24·91	29·16	31·58	31·39	28·92	28·78	28·87	26·47	29·90	31·88

It would thus appear that, as far as we can judge from such limited data, there are, as in the case of rivers, and probably rainfall, traces of a double maximum for one of sun-spots. This, however, is a conclusion that cannot at present be regarded as established, but only as more or less probable.

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5. *On apparent Sun-spot Inequalities of Short Period. By* Professor Balfour Stewart, *F.R.S., and* W. Lant Carpenter, *B.A., B.Sc.*

By means of a method for detecting inequalities of unknown period in a mass of observations, which has already been described to this Association, we have made some way in analysing sun-spot records, and have detected several apparent inequalities of short period, while we are in hopes that we shall be able to show that there is a definite relation between these and corresponding inequalities in meteorology and magnetism.

We do not intend at present to raise the question as to the true or merely apparent periodicity of these inequalities. We simply take them as we find them, and see whether there are corresponding apparent inequalities in meteorology and magnetism, for it is obvious that there may be a true relation between celestial and terrestrial inequalities quite apart from the question of their true periodicity.

Meanwhile it may be of interest to the Association to exhibit the most striking evidence of repetition which we have obtained in the progress of our sun-spot analysis. The observations analysed have been those of Schwabe, Carrington, and De la Rue, extending over a period of thirty-six years, and these have been divided into three periods of twelve years each. The inequalities for each year are proportionally represented, so that each carries equal weight whether it be a year of maximum or minimum sun-spots. In doing this the average of spots for each year is reckoned = 1,000, the departures of each term of the year's inequality from this average number being noted—in red when deficient, and in black when in excess.

As the departures for each year are added algebraically together, it will be necessary for the twelve years series to divide the sums red or black by twelve, in order to estimate the true extent of the inequality, and in like manner it will be necessary to divide the sums for thirty-six years by thirty-six. When this is done we shall have the true measure of the positive (black) and negative (red) departures from the mean (1,000). In the following table, the numbers of which have not been submitted to any smoothing process, we have represented the two most prominent sun-spot inequalities which we have hitherto detected. It will be seen from these that there is in each very marked evidence of repetition, the results for the twelve years being very like each other.

Dividing the gross results by thirty-six, we have in the first of these inequalities

a positive departure = 124 and a negative = 89, representing a range between extreme values of 213 for a mean value of 1,000. Again, in the second inequality we have a positive departure = 131 and a negative = 104, representing a range between extreme values of 235 for a mean value of 1,000. In both cases, therefore, the range of oscillation is between one-fourth and one-fifth of the mean value.

TABLE OF SUPPOSED SUN-SPOT INEQUALITIES OF SHORT PERIOD.

Period = 26·089 Days				Period = 26·255 Days			
1832–43	1844–55	1856–67	Whole	1832–43	1844–55	1856–67	Whole
+ 159	− 224	− 66	− 131	− 535	− 1,037	− 775	− 2,347
− 380	− 286	− 390	− 1,056	− 1,131	− 1,417	− 782	− 3,330
− 416	− 628	− 331	− 1,375	− 1,031	− 1,345	− 994	− 3,370
− 452	− 405	− 380	− 1,237	− 1,618	− 832	− 882	− 3,332
+ 32	− 884	− 608	− 1,460	− 1,283	− 819	−1,146	− 3,248
− 181	− 740	− 616	− 1,537	− 1,383	− 1,151	−1,224	− 3,758
− 723	− 496	− 482	− 1,701	− 1,231	− 642	−1,424	− 3,297
− 258	− 673	− 753	− 1,684	− 683	− 617	− 522	− 1,822
− 399	− 675	− 1,361	− 2,435	− 1,101	− 1,045	− 412	− 2,558
−1,306	− 475	− 1,214	− 2,995	− 1,445	− 834	− 350	− 2,629
−1,250	− 553	− 1,421	− 3,224	− 573	− 174	− 252	− 999
− 808	− 225	− 1,201	− 2,234	+ 244	+ 404	− 92	+ 556
− 706	− 194	− 883	− 1,783	+ 11	+ 271	+ 198	+ 480
− 342	+ 11	− 1,284	− 1,615	+ 128	+ 259	− 126	+ 261
+ 4	+ 1	− 667	− 662	+ 573	+ 933	+ 316	+ 1,822
− 35	+ 220	+ 51	+ 236	+ 1,490	+ 823	+1,124	+ 3,437
+ 527	+ 407	+ 316	+ 1,250	+ 1,653	+ 1,490	+1,597	+ 4,740
+ 304	+ 583	+ 272	+ 1,159	+ 1,381	+ 1,653	+1,791	+ 4,825
+1,310	+1,128	+ 800	+ 3,238	+ 1,459	+ 1,613	+1,723	+ 4,795
+1,511	+1,600	+ 1,335	+ 4,446	+ 1,442	+ 1,308	+1,132	+ 3,882
+ 567	+1,110	+ 1,319	+ 2,996	+ 1,242	+ 919	+ 560	+ 2,721
+ 493	+1,026	+ 1,418	+ 2,937	+ 710	+ 885	+ 413	+ 2,008
+1,232	+ 424	+ 1,977	+ 3,633	+ 535	+ 572	+ 290	+ 1,397
+ 584	− 110	+ 1,935	+ 2,409	+ 722	+ 50	+ 178	+ 950
+ 318	+ 172	+ 1,633	+ 2,123	+ 408	− 376	− 261	− 229
+ 215	− 114	+ 601	+ 702	+ 16	− 891	− 80	− 955
+7,256	+6,682	+11,657	+25,129	+12,014	+11,180	+9,322	+31,874
−7,256	−6,682	−11,657	−25,129	−12,014	−11,180	−9,322	−31,874

The first number in each case represents the phase corresponding to January 1, 1832.

6. *On the Forms of the Influence exerted by the Sun on the Magnetism of the Earth. By* Professor BALFOUR STEWART, *F.R.S.*

The object of the present paper is not so much to offer an hypothesis on the physical nature of the sun's influence on the magnetism of the earth, as to present the various facts already known regarding this influence in a systematic form. If in doing so an hypothesis of solar action shall be brought forward, it must be regarded simply in the light of a working hypothesis, which may prove serviceable as a thread on which to string the facts.

One way in which the sun influences the magnetism of the earth is in producing the well-known daily variation. Of this the variation of magnetic declination is the element which is best known, and the chief peculiarities of this may be described in a very few words. In the northern hemisphere the north end of a

freely suspended magnetic needle will attain its most easterly position about 7 or 8 in the morning, and its most westerly about 1 or 2 in the afternoon, while in the southern hemisphere the same end of the needle will be affected in a manner exactly the reverse of this, the extreme west being attained about 8 in the morning, and the extreme east about 2 in the afternoon. It thus appears that the type of this variation is of an opposite nature in the two hemispheres. Furthermore, when the sun is north of the equator during our summer the northern type predominates, and to some extent invades the other, so that the variation in the northern hemisphere is increased, while that in the southern is diminished. During our winter precisely the reverse takes place; the variation in the southern hemisphere being increased, while that in the northern is diminished. Thus in either hemisphere the diurnal variation is greatest in summer and least in winter—that is to say, it is greatest when the sun acts most powerfully at the place of observation.

Again, the range of this variation is greatest at times of maximum sun-spots, but the effect which the state of the solar surface produces upon the range lags in point of time behind its solar cause, so that a maximun of magnetic range does not take place until some time after a maximum of sun-spots. The most obvious inference from this mode of action would seem to be that the magnetic effect is due in some way to the indirect influence of solar radiation, and that this radiation is strongest when there are most sun-spots. So much for the best known effect of the sun upon the magnetism of the earth.

The second effect to which I will now allude was first noticed by the late John Allan Broun, who showed that changes of the earth's horizontal magnetic force, whether tending to its increase or diminution, takes place nearly simultaneously at the various recording stations of the earth. Here the horizontal component may in all probability be regarded as giving us a convenient means of measuring changes of total force, so that what these observations seem to imply is that the total magnetic force of the earth changes simultaneously at these various stations. I have recently found, on comparing Broun's results with the state of the sun's surface, that an increase of the earth's horizontal magnetic force corresponds to an increase of sun-spots, and a diminution of the earth's horizontal force to a diminution of sun-spots, the effect here, as in the previous instance, lagging somewhat behind its cause in point of time. The difference between the two solar effects now described would appear to be that in the former (the diurnal change) we have a superposed variation of a different type from the earth's system, while in the latter we have a variation having the same type as that of the earth, or at least which may possibly be regarded as having the same type. Now the earth's magnetic system is a polar one, and hence if the sun affects this system as a whole we may imagine that he does so by a variation of his influence (whatever this may be) over the north magnetic pole, or over the south magnetic pole, or over both poles together. Should the state of the sun's surface vary—say, for instance, in the direction of an increase of power—we may imagine that this would influence both poles.

But, apart from intrinsic changes of the solar surface, the sun during our summer may be imagined to exert a particularly powerful influence over the north magneticpole, and during our winter over the corresponding pole in the southern hemisphere. Again, a strong influence at either pole may reasonably be supposed to affect the whole system, so that we might, perhaps, on theoretical grounds expect a strengthening of the earth's magnetic system twice a year—namely, at the solstices, the one being due to the polar action of the sun in the northern, the other to his polar action in the southern hemisphere.

Now a semiannual variation of this nature has in fact been observed by Broun, who has made his analysis so carefully that his results cannot be attributed to mere instrumental changes. We have from these an increase of the earth's horizontal component at the solstices as compared with the equinoxes. In order to elucidate this point, I have gathered together the various trustworthy determinations of the annual and semiannual variations of declination, horizontal force, and dip at stations in both hemispheres. These are exhibited in the following table:—

TABLE SHOWING THE ANNUAL AND SEMIANNUAL VARIATIONS OF THE MAGNETIC ELEMENTS AT SEVERAL STATIONS.

Name of Station	Effect on Declination[1]		Effect on Horizontal Force		Effect on Dip	
	At Equinoxes compared with Solstices	At June Solstice compared with December Solstice	At Equinoxes compared with Solstices	At June Solstice compared with December Solstice	At Equinoxes compared with Solstices	At June Solstice compared with December Solstice
Makerstoun or Kew.	Increase	Decrease	Decrease	Inappreciable	Increase	Decrease
Toronto . . .	Increase	Decrease	Decrease	Increase	Inappreciable	Decrease
Cape of Good Hope .	Increase	Decrease	Decrease	Increase		
Hobarton . . .	Decrease	Decrease	Decrease	Decrease	Decrease	Decrease
Trevandrum . .	Decrease	Increase				
Bombay . . .	Undecided	Increase				
St. Helena. . .	Undecided	Decrease				

[1] *Increase* denotes a push to the west. *Decrease* denotes a push to the east.

From this table it will be seen that at all stations where observations have been made the horizontal force is, as we have stated above, greater at the solstices than at the equinoxes. Also we may imagine that the changes of declination and dip which the table exhibits as occurring at the solstices are the very changes which would be wrought in these elements by an increase in the magnetic power of the earth. For we see very well that an increase of horizontal force at the various stations is what might naturally be associated with an increase in the earth's magnetic power. We cannot, however (inasmuch as the earth has the appearance of possessing two magnetic systems), see with equal facility what changes would be produced in the declination or dip by an increase in power of one or other of these systems; but we may well imagine that such changes of these elements as are found to accompany an increase of horizontal force are those that denote an increase of power in one or other of these systems. Now it will be seen by an inspection of the table that the effect at the June as compared with that at the December solstice is in all cases but one, of an exactly opposite nature to the effect at the equinoxes as compared with the solstices; that is to say, the earth is more powerfully affected at June than at December, the only well-established exception being Hobarton, in the far south. This means that the polar influence of the sun on the north magnetic pole is stronger than its polar influence on the south magnetic pole. Now, if we imagine (and there are grounds for this supposition) that the action of the sun is in close alliance with the convection system of the earth's atmosphere, we can readily imagine that its influence in the northern hemisphere, where there is much land, may exceed that in the southern hemisphere, where there is much water. Again, we must bear in mind (so vast is the earth) that a stimulus applied to its particles most susceptible of magnetisation may not be instantaneously propagated throughout its mass, but that time may enter in as an element of the question, in which case, inasmuch as the action of the sun in the June solstice is in the northern hemisphere, a station in the far south, like Hobarton, may not fully partake of the effects of this action. Allusion has been made to the possibility of the earth's possessing two magnetic systems, a permanent and an induction one; at any rate there are two foci of force in each hemisphere, the stronger of which in the northern hemisphere is above America, and the weaker above Siberia. There is evidence too that the Siberian focus is most subject to external influence, and that certain disturbances of declination change their direction on different sides of this focus. Let us, therefore, assume that it is this system which exhibits the annual and semiannual changes. In this case we might expect that the influence on declination at Toronto and Kew, which are on one side of the Siberian focus, will be opposite to that at Trevandrum and Bombay, which are on the other side. We find from the table that this is the case, and that

the needle at the solstices, and particularly the summer solstice, is at Kew and Toronto pushed to the east, while at Trevandrum and Bombay it is pushed to the west, as if the north induction system had become particularly powerful on these occasions. In conclusion, I wish to state that these remarks are introduced rather as denoting a method of grouping together the annual and semiannual observations than as embodying conclusions of a final nature. This working hypothesis may be summarised as follows:—

(α) The sun's polar influence on the earth's magnetism is greatest at the solstices.

(β) This effect is stronger at the June than at the December solstice.

(γ) It seems particularly to affect what has been termed the induction magnetic system of the earth.

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7. *Description of a Marine Anemometer.* *By* Dr. W. G. Black, *F.R.M.S.*

This instrument is designed on the idea of registering the pressure of the wind on the sail of a ship for the purposes of the navigator.

It therefore consists of a hollow mast, carrying a square sail, suspended from a fixed yard at the head, and having a free foot stretched on another yard below.

The tube of the mast contains a spiral spring at the upper half, with a pointer outside, and from this proceeds the sheet or a cord, going under a pulley at the lower end, to be attached to the lower yard of the sail.

The heel of the mast can be secured by suitable plinth and screw, and placed on a railing or other likely structure on the bridge of the ship or steamer.

A movable vane surmounts the head of the mast, and the sail can be turned by hand to face the full direction of the wind, and the pressure on the sail can then be read off on the scale on the side. This scale is marked in inches and pounds and their parts, temporarily in the ratio of one inch to four pounds.

Estimation of the true direction of the wind and its velocity and force can thus be obtained by constructing a diagram of parallelogram of forces of the wind and rate of sailing. The diagonal would be furnished by the perpendicular line to the face of the sail pointing to the apparent wind, and the required angle would be read off from the dial of degrees marked on the circumference of the lower plinth.

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8. *On a Method for Measuring the Height of the Clouds.* *By* Professor Lüroth.

This method simply consists of taking a strong electric lamp, together with a reflector and a tube, and directing a pencil of luminous rays, say vertically, against the sky. These rays will produce within the cloud that occupies the zenith a luminous spot, and it is only needful to determine the angular elevation of that spot above the horizon from a distant point, whose position with respect to the lamp is known; hence the calculation of the height in question will be but one of the simplest tasks in plane trigonometry. The method will of course best be applicable during night, but it might also be used by daylight, if the sunshine is not too bright. Still there might be limits as to the height for measuring which the method is capable of being adapted.

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9. *On Fixing a Standard of White Light.* *By* Captain Abney, *F.R.S.*

The author described an instrument which he had devised nine years ago, and had used for comparison of the electric light and gas-light when serving on a Government Committee. The comparison of incandescence light proved to be highly instructive; and eventually it was found that for obtaining a standard light of high temperature, nothing could be better except the crater of the positive pole of the electric arc. This latter has invariably the same temperature, as was shown by the author and Colonel Festing in a paper which has recently appeared in the *Proceedings* of the Royal Society. It has, however, one insuperable drawback as

a standard of white light, in that it is surrounded to a greater or less degree with carbon vapour, which, though radiating but little energy, yet radiates that energy chiefly as bright bands in the green and the blue of the visible spectrum. Could these bands be eliminated there is a temperature which is apparently constant, and which, consequently, will radiate also the same proportionate intensity of rays. Failing this, the incandescence lights offer the next best standard; and though when compared with daylight of an ordinary character they appear yellow even at their highest practicable temperature, yet they are much whiter, containing more proportionate green, blue, and violet than gas-light, taking the red near the C line as equal in both cases. Again, we have another decided advantage over gas in the fact that the body heated is a solid, and, for practical purposes, black. In gas-light there is a decided preponderance of yellow and orange, compared with a solid heated to the same temperature. Hence the 'spectrum range,' to coin a word, is more accurate with the incandescent lamp than with the gas. A point that required investigation was as to whether all carbon-threads emitted the same relative proportion of spectrum rays, and it was found that they did so, and that at what is believed to be the same temperature, the proportion of these rays remained constant. (The proportion was obtained by comparing it with ignited coal gas.) Hence we arrive at one step in fixing a standard quality of light. The question arises as to what temperature the carbon filament may be heated without endangering the existence of the lamp. At one stage of heat in the carbon-thread of a well-exhausted lamp there is a peculiar glow, which illuminates the bulb of the lamp, and if that glow be examined by the spectroscope it will be found to consist of four or five bright lines, due to carbon vapour in some shape or another; and if that temperature be maintained the carbon is found to be deposited as an impalpable powder on parts of the glass globe, and eventually the thread breaks at the place of greatest resistance. Below this heat the thread will remain unaltered for many hours without any apparent change, always supposing the thread to have been previously heated to such a degree as to give constant resistance at freezing point. This is a matter of some importance, as in the experiments made new lamps increased in resistance after a few hours' ignition as much as five per cent., and after that remained constant, when heated to a temperature below that already indicated. An investigation then took place regarding the intensity of radiation from an incandescent carbon filament and the energy and temperature. The results of these experiments are given in the 'Phil. Mag.' September 1883, in which it will be seen that after a certain temperature (dependent on the thickness of the filament and the temperature of the surroundings) the radiation and the energy expended are directly proportional. A good fiducial temperature is when the carbon-thread is just visible to the eye when examined in a darkened room, and is very nearly 530° C. If the energy at this temperature be accurately measured by means of the current and the electro-motive force, and if the resistance be measured at the temperature of melting ice, the temperature of filament at just below the point below which the carbon lines appear can be readily obtained by diminishing the resistance of the carbon filament by half. This has been found to be approximately the temperature required. Another check-method is to note the radiation by means of the thermopile at the point of first visible incandescence, and to increase the energy expended till the radiation noted is forty times as great. This can be effected with great facility, and the quality of light radiated is in this case invariably the same, as it is indeed if any other proportion be taken.

It may be well to note here the expressions which exist between—Watts, W; radiation, D; potential, P; current, C; resistance, R; temperature, T.

$$\mathrm{C} = ap + bp^{\frac{3}{2}}$$

$$\mathrm{W} = p^2 (a + bp^{\frac{1}{2}})$$

$$\mathrm{R} = \left(\frac{1 - ar}{br}\right)^4 \cdot \frac{1}{r}$$

$$\mathrm{D} = m + n\mathrm{W}$$

$$\mathrm{T} = \frac{k}{r}$$

(This last expression is correct for all practical purposes, but requires a few further experiments to ascertain the correctness of the law with greater exactitude.)

a, b, m, n, and a are of course constants, which require determination for each lamp.

The mode of ascertaining these constants was then described, by means of which a curve of potential and current can be plotted, and the constants a and b calculated by the method of least squares, if necessary. From the observed currents and potentials the Watts can be calculated, and also from the corrected currents and potential, the latter being found to be more accurately observed than the former. The same curve is adopted for the resistances. The resistances, current, and Watts will be found to be nearly coincident when calculated from the direct observations or from the corrected curves of current and potential. To find the constant n the observations of corrected Watts and deflections are plotted, the one as ordinates, and the other as the abscissæ to the curves, when it will be found that the curve at any temperature above 530° C. is a straight line, and n is thus readily obtained either by calculation or by a graphic method, as is also m.

The constant k can be obtained by observing the resistance at 530°, the temperature when luminous radiation just commences.

By this plan all constants are known, and any required temperature can be obtained by increasing the potential, and if necessary introducing a known resistance in the circuit. In choosing an incandescent solid, however, there are certain conditions that require attention. In the first place the section of the radiating body should be uniform, and also homogeneous. The carbon threads such as those prepared by Edison meet this condition as fully as practicable. This may be readily ascertained by passing a current of such an intensity through the filament as just to cause it to be at a red glow when seen in a darkened room. If the filament be uniform in section and homogeneous, the glow will be seen to be equally bright in every part of its length, no dark patches being apparent. Another condition which also should be fulfilled theoretically is that the body should radiate on to matter which is everywhere of uniform temperature, or nearly so. In an ordinary incandescence lamp this is not quite the case, for if the filament be of the form of a simple loop, the two legs must radiate one on to the other, and the inner surfaces should have a higher temperature. At the distance apart at which these legs are placed this difficulty does not arise, but in making a standard lamp it is proposed that it should radiate from a single thread. The best method of construction of such a lamp the Committee propose to submit in a subsequent report.

The light which it is proposed to employ as a standard of quality is as follows. Taking the colour of Mr. Vernon Harcourt's standard as a comparison light—the red (at the C line of the solar spectrum) being taken as equal in the two lights, the light at E in the new standard should be 1·5 times that of the gas-light; the increase in intensity of the higher radiations will then follow of necessity. Compared with the electric light this increase in the green is small, as the increase in the green of the crater light (positive pole) is very nearly three times that of gas-light.

When possessed of one lamp of which the necessary constants for the production of the standard temperature are known, any other lamp which has a uniform filament may be standardised by direct comparison with it by increasing or diminishing the current till the shadows as thrown by the Rumford photometer on a white screen appear of the same tint. It will be found that a very slight alteration in current from the point at which the shadows appear equal in brightness and similar in colour will alter the latter. By this plan the original standard may be preserved for a considerable period, the second lamp taking its place in all photometric or other experiments.

The method of obtaining an exact *quality* of light has now been indicated, and the quantity of light radiated can easily be proved by direct experiment. It is proposed that the amount of candle-light (so called) be obtained by measuring with a photometer the standard light proposed by Mr. Vernon Harcourt with the lamp at the given temperature, the observation being made through a cell, the plates of which are 1 mm. apart, filled with an aqueous solution of iodine and iodide of potassium made as follows:—

Iodine	1 centigramme.
Potassium iodide	2 centigrammes.
Distilled water	10 c.c.

The cell, filled with this solution, to be held between the eye and the photometer whilst the observation is made, in order to render each light of approximately the same colour. When using the lamp as a standard of quantity the loop of the filament should be vertical and its plane at right angles to the photometer screen. It will be seen that by this plan a lamp of any 'quantity' may be standardised, so as always to radiate the same 'quality' of light.

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10. *On the Dependence of Total Radiation on Temperature.* *By* Sir WILLIAM SIEMENS, *D.C.L., F.R.S.*

On April 25, 1883, the author presented a paper bearing the same title to the Royal Society, in which he developed a method of determining the total radiation and the temperature of a metallic conductor traversed by an electric current by measuring that current and also the electric potential between the terminals.

In an article appearing in the 'Philosophical Magazine' of September 1883, by Captain Abney and Colonel Festing, these authors admit the method to be one of 'great promise,' but consider it defective for two reasons, viz., that

(1) Platinum (the conductor employed in some of the experiments) is not black at ordinary temperatures, and

(2) Much of the energy must have been dissipated by convection currents.

They proceed to describe a modification of the same method, substituting carbon filaments in vacuum—such as Swan or Lane Fox lamps—for the metallic conductors, with a view of avoiding the difficulties just stated. Following up the same modified method, Captain Abney now proposes to base upon it a method of fixing a standard of white light.

Sir William Siemens takes exception to this proposal, maintaining in the first place that the objections urged against his method admit of explanation, and in the next that the proposed substitution of carbon for metallic conductors would introduce questions of great difficulty.

The objection raised against platinum wire that it is not black when cold would be easily met by the substitution of platinised platinum wire, and, in testing the black platinised against the bright platinum wire, an interesting comparison between the radiation from a *black* and *bright* surface through a long range of temperature could be established. In exposing the wire under examination to the atmosphere convection currents were no doubt set up which went in deduction of total radiation. To avoid these he had suspended his wires within exhausted receivers, but found that the atmospheric density made no appreciable difference in the result. When the gaseous pressure was reduced below that of a millimetre of mercury, the loss of heat otherwise than by radiation was observed to increase on the contrary, pointing to the fact, previously determined by Mr. Crookes, that rarefied air is a conductor of heat.

But, supposing that the rarefaction within the bulb of an incandescence lamp exceeds the limit at which conduction takes place, losses by convection currents must nevertheless take place, exceeding those from the unprotected wire, because the glass bulb itself absorbs a large proportion of both the low heat and the ultra-violet rays—as evidenced by its elevated temperature—which heat was communicated to the air by convection currents. It must be borne in mind that the surface of the bulb exceeded that of the ignited carbon thread nearly a hundredfold, giving rise to increased loss by convection.

The substitution of carbon for metallic wire was, moreover, objected to on the ground that although the electrical resistance furnished a safe indication of temperature in the case of metallic conductors, carbon was known to be affected very irregularly in the opposite sense. Those physicists who had endeavoured to establish a law of dependence between temperature and conductivity of carbon-

rods had failed hitherto to arrive at any consistent results, and it would be necessary under these circumstances that such dependence should be established upon a firm basis before it could be admitted as an accomplished fact in photometry.

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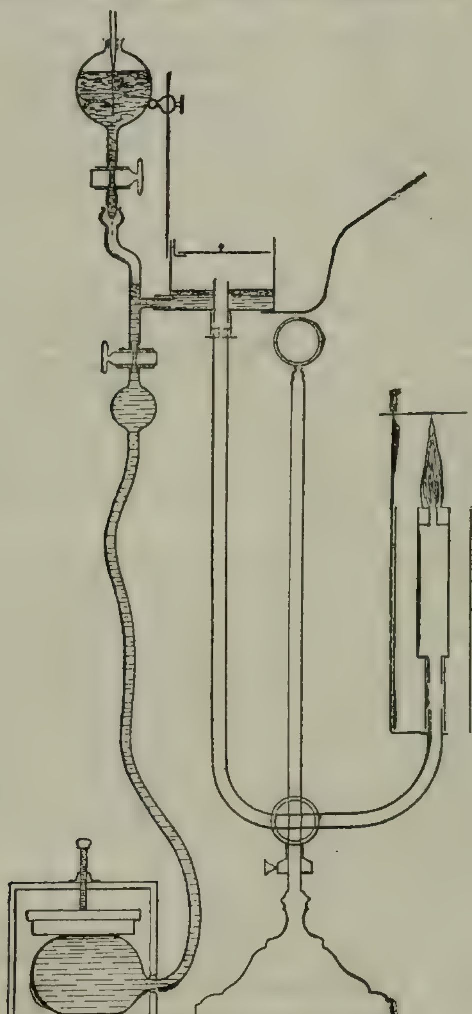
11. *On a Lamp giving a Constant Light.* *By* A. VERNON HARCOURT, *M.A.*, *F.R.S.*

Six years ago the need of a standard light for photometry, and a proposal to obtain such a light from a burner of simple construction, consuming a definite mixture of air and petroleum vapour, were brought before this Section. The composition of the 'air-gas' and the height of the flame were so adjusted that the light, which was easily kept constant, was equal to the average light of one of the sperm candles made for photometry. Two years later, the attention of the Board of Trade



having been called to the uncertainty as to the quality, or price, of gas supplied by the gas companies, arising from the variable character of the standard candles, a committee, consisting of Dr. Williamson, Dr. Odling, and Mr. G. Livesey, was appointed to inquire into existing and proposed photometric standards. After a prolonged inquiry, the details of which are printed in a Report to the Board of Trade, the committee pronounced sperm candles to

be untrustworthy as a standard of light, and recommended the employment in their stead of the air-gas flame. At present the Board of Trade have taken no action upon this Report, and the quality of the gas which the companies are to supply remains in the hands of the candle-makers. The lamp now placed before the Section, and represented by the above figure, is the result of an attempt to bring the air-gas standard into favour by giving it a simple and portable form. The burner and the flame are identical with those to which reference has been made. But to form the standard gas, instead of 3 cubic feet of air mixing in a holder with 1·05 cubic foot of vapour formed from 9 cubic inches of standard petroleum, or pentane, the air and vapour mix in a small reservoir, and thence flow down to the burner. At one point the diameter of the pipe through which they flow is reduced, and this reduction and the height of the reservoir are so related that when a mixture in the above-named proportions is entering the pipe it burns with a flame of the standard height of $2\frac{1}{2}$ inches. In constructing the lamp the aperture in the tube or height of the reservoir was varied until the light given by the lamp was exactly equal to that given by the standard flame obtained from air-gas made up in the holder. With a lamp thus constructed the height of the flame depends upon the proportion in which air and the heavy vapour are mixed. If there is more air the density of the mixture and the consequent flow are reduced; and also the poorer gas burns with a shorter flame. If there is more pentane vapour the density of the mixture and the consequent flow are increased; and also the richer gas burns with a longer flame. Thus to each height of flame belongs, for the same lamp, a particular mixture of air and vapour. This lamp has been so made that the standard mixture produces—and no other mixture can produce—the standard height of flame. The flame of the lamp is therefore identical with the pentane flame which has been tested and used hitherto. And, as the construction of the lamp involves no small measurements, other lamps can readily be made which, fed with the same liquid and adjusted to give a $2\frac{1}{2}$-inch flame, will give the same light as this lamp.

The means by which the height of the flame may be adjusted will be understood from the figure. By the turning of a screw water is forced into the reservoir, and the surface of the pentane which floats upon the water is raised nearer the mouth of the pipe down which the air-gas flows. The proportion of pentane vapour is thus increased; it is diminished by lowering the level. A supply of pentane approximately equal to the consumption is furnished from a bulb and stopcock which delivers a drop about once in five seconds; and a supply of heat is brought by a rod and disc extending above the flame at a distance and inclination which must be varied according to the temperature of the room in which the lamp is used. It is only necessary that the supply of heat should not be so small as to require the raising of the pentane to the top of the pipe, nor so large as to give a high flame when the surface of the liquid is at a low level. None of the adjustments named has been found difficult in practice.

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12. *On some Results of Photographing the Solar Corona without an Eclipse. By* William Huggins, *D.C.L., LL.D., F.R.S.*—See Reports, p. 346.

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13. *On the Internal Constitution of the Sun. By* Professor Arthur Schuster, *F.R.S.*

The idea that the sun is a gaseous body is gradually gaining ground. It could not be otherwise, for the interior of the sun cannot be permanently at a lower temperature than the surface, which we know to be sufficiently hot to volatilise some highly refractory metals.

If the sun is a gaseous mass it must be in convective equilibrium, and the distribution of temperature within it must be determined by the adiabatic law. Only thus could its small density be explained.

Opinions such as these have been independently expressed in different parts of the world, but no one, the author thinks, has subjected them to the test of calculation.

It is rather curious that, as far as he is aware, the problem of the internal equilibrium of a gaseous gravitating mass has not as yet been discussed. Such a mass will arrange itself in concentric layers round its centre of inertia, and the question arises, What is the distribution of density and pressure within? It is exceedingly probable that the problem has been attempted, for it is perfectly easy to write down the differential equation which contains the result. But then the differential equation has to be solved. If we suppose the temperature constant throughout the gas, we cannot express the result in closed form; if the temperature is regulated by the adiabatic law, we must take account of the ratio between the two specific heats. For two different values the equation can be solved, and as the ratio for all known gases happens to lie between these values, we may at any rate get some information from a consideration of these special cases. If the ratio between the two specific heats is 1·2, the following system of equations gives the result:—

$$p=\frac{27}{A^3(2\pi g)^{\frac{3}{2}}}\qquad\frac{c^3}{(c^2+r^2)^3}$$

$$\rho=\frac{9\sqrt{3}}{A^{\frac{3}{2}}(2\pi g)^{\frac{5}{4}}}\qquad\frac{c^{\frac{5}{2}}}{(c^2+r^2)^{\frac{5}{2}}}$$

$$M=\frac{6\sqrt{3}\sqrt{c}}{A^{\frac{3}{2}}g^{\frac{5}{4}}(2\pi)^{\frac{1}{4}}}\qquad\frac{r^3}{(c^2+r^2)^{\frac{3}{2}}}$$

Here p represents the pressure; ρ, the density; r, the distance from the centre of mass; g, the constant of gravitational attraction; M, the total mass within sphere of radius and round the centre of mass; c is a constant of integration to be determined by the conditions of the problem, and A depends on the nature of the gas $(\rho=Ap^{\frac{5}{6}})$. The total mass of the gas is $\frac{6\sqrt{3}\sqrt{c}}{A^{\frac{3}{2}}g^{\frac{5}{4}}(2\pi)^{\frac{1}{4}}}$, as we see by putting r infinitely large in the last equation.

The gas extends to an infinite distance, as only there the density and pressure vanish; the distribution of temperature is, of course, also determined by the equations.

The second case, for which the differential equation is easily solved, is that in which the gas has its specific heat for constant pressure exactly twice that of constant volume. With the same notation as above, only putting $a=A\sqrt{2\pi g}$,

$$\sqrt{p}=\frac{c}{r}\sin ar$$

$$\rho=\frac{Ac}{r}\sin ar$$

$$M=\frac{2c}{gA}(\sin ar-ar\cos ar).$$

Here the mass of gas is limited, for the equations have only sense as long as ar remains between o and 2π. When, therefore, r has become equal to $\frac{a}{2\pi}$, the pressure and density are nothing, and the total mass is equal to $\frac{4\pi c}{gA}$.

It would be interesting to inquire for what value of k (the ratio of the two specific heats) the mass begins to arrange itself into a finite sphere. The author believes that this occurs when this ratio is equal to $\frac{4}{3}$, but cannot offer any absolute proof. The highest value which k can have is $1\frac{2}{3}$, and this value holds approximately for mercury vapour; it is very probable that the value of k in the interior of the sun, where molecules will no doubt be broken up, as far as they can be broken up by heat, will not be far from the same number. To follow out the calculation in this

case we should have to use approximate methods, and these are very difficult to apply to our special problem.

He will therefore in the present paper confine himself to the two cases which can be accurately solved, and give the answer to the following question: What would be the radius of a sphere having on its surface a temperature such as that we approximately know, and also having a vapour-density not far different from that of known bodies? If the ratio of the two specific heats is 1·2, he finds that, taking account of the total mass, the radius of the sun would have to be more than a million times larger than it really is; no possible value for the temperature of the surface or the mass of the sun could bring the radius within the required limits.

Taking the second case, or $k=2$, we find that for the same surface condition the radius of the sun would have to be very small indeed—almost vanishingly small. The enormous difference in the results for the two values of k is surprising, but it is so far satisfactory as our sun has a radius which is, as it ought to be, intermediate between the two extreme values.

One more interesting question, which he will mention only in this place, can be easily discussed by means of our equations. It is that which refers to the change of temperature and size of a gaseous body owing to loss of heat by radiation.

TUESDAY, SEPTEMBER 25.

The following Papers were read:—

1. *Note sur les Résultats de ses Observations de l'Eclipse totale du* 6 *Mai* 1883, *à l'Ile Caroline* (*long.* 152° 20′ *ouest, Paris, lat.* 10° *sud*), *Océan Pacifique.*[1] *By* Dr. J. Janssen.

Observations optiques.

L'auteur s'était principalement proposé de résoudre la question des raies obscures de Fraunhofer dans le spectre de la couronne.

Cette question ayant une grande importance pour la constitution de la couronne et des espaces circumsolaires, il était important qu'elle fût résolue définitivement.

En 1871 l'auteur avait annoncé avoir découvert dans le spectre de la couronne quelques raies obscures, D, *b*, etc. Ce résultat fut confirmé par quelques observateurs et non confirmé par d'autres.

Toutes les dispositions instrumentales furent prises cette fois-ci en vue d'obtenir un spectre de la couronne plus lumineux que ceux obtenus jusqu'ici.

Le télescope employé porte un miroir qui a 0·50 c. de diamètre, et seulement 1 m. 60 de distance focale. Le spectroscope est à vision directe extrêmement lumineux. Tout l'instrument a été construit sur le plan de celui employé en 1871 et décrit dans le rapport publié alors.

Par ces dispositions l'auteur a pu reconnaître—

Qu'en général le spectre de la couronne présente le spectre fraunhoférien complet (excepté bien entendu les raies brillantes propres à la couronne).

Les raies D, *b*, E, etc., étaient on ne peut plus acceptées. On a vu une centaine de raies peut-être.

Le phénomène s'est montré dans les parties très-brillantes de la couronne, mais non tout-à-fait à la base où le spectre paraissait continu.

Le phénomène ne s'est pas montré avec la même intensité à des distances égales du limbe lunaire.

Les anneaux de Respighi ne se sont pas montrés réguliers autour du limbe lunaire, mais leurs formes rappelaient celles de la couronne elle-même.

[1] *Comptes Rendus de l'Académie des Sciences*, seance Septembre 3, 1883.

La présence du spectre fraunhoférien complet dans la lumière de la couronne indique la présence d'une abondante quantité de lumière d'origine solaire.

Une proportion de cette lumière peut devoir son origine à la diffraction, mais cette cause ne pourrait expliquer que la présence d'une faible partie de cette abondante lumière. La très-grande partie est nécessairement due à la réflexion. Et comme nous savons d'ailleurs que les gaz qui forment l'atmosphère coronale sont très-rares, il faut nécessairement que cette réflexion ait lieu sur des matériaux de grande densité solides ou liquides.

D'un autre côté nous savons aussi que des comètes ont passé très-près de la surface solaire, et qu'elles ont dû traverser les régions en question. Ces comètes n'auraient pu traverser des milieux gazeux à forte densité sans y rester.

Par l'ensemble des phénomènes on est conduit à admettre dans ces régions de la couronne des corpuscules solides ou liquides circulant autour du soleil et produisant ces phénomènes d'abondante réflexion de lumière solaire que le spectre fraunhoférien nous accuse.

Photographies.

Les appareils photographiques employés avaient des objectifs de $4p$, $6p$, $8p$, de diamètre.

Le but principal que je m'étais proposé était de constater, 1°, si l'étendue de la couronne augmente indéfiniment avec le temps de pose; 2°, si les formes de la couronne sont fixes pendant toute la durée de la totalité.

Il a été constaté, nombre de fois, que l'étendue de l'image photographique de la couronne augmente d'étendue quand le temps d'exposition, d'abord tres-court, croît ensuite successivement. Or, on peut se demander si le phénomène croît indéfiniment ou s'il est limité.

Nos photographies montrent que le phénomène est limité. Des images de la couronne obtenues avec des objectifs de pouvoirs lumineux très-différents, mais correspondant à une même durée de l'action lumineuse, ont la même étendue. Il résulte de cette expérience que la couronne a des limites, et que, quand la pose est assez longue, en raison du pouvoir lumineux de l'instrument, une pose plus prolongée ou un pouvoir lumineux plus grand n'ajoute pas sensiblement à l'étendue de l'image obtenue. Ainsi la couronne est un phénomène qui a des limites dans le ciel.

La couronne a conservé des *formes fixes* pendant la durée de la totalité.

Nos appareils photographiques pour la couronne étaient réglés sur le mouvement du soleil. Comme la lune a un mouvement relatif assez rapide par rapport au soleil, nos photographies montrent ce mouvement relatif de la lune dont l'image sur les photographies est de forme elliptique; mais ce qui est très-remarquable, c'est que les formes et les détails de l'image coronales sont très-nettes, quoique les plaques fussent restées exposées pendant tout le temps de l'éclipse, et ce fait montre que le phénomène est bien réel, et que la part de la diffraction dans la couronne est sinon nulle au moins très-faible.

De l'ensemble des observations qui seront discutées il résulte suivant l'auteur—

1°. Que la couronne des éclipses totales est en grande partie un phénomène d'origine solaire et circumsolaire.

2°. Que ce phénomène est limité.

3°. Que la lune et l'atmosphère terrestre interviennent pour modifier l'aspect de la couronne.

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2. *On the Involution of Two Matrices of the Second Order.* *By* Professor J. J. Sylvester, *F.R.S.*

If m, n be two matrices of any order i, then, taking the determinant of the matrix $z + yn + xm$, there results a ternary quantic in the variables x, y, z, which may be termed the quantic of the corpus m, n.

In what follows I confine myself almost exclusively to the case of a corpus of the second order; the quantic may be written $z^2 + 2bzx + 2cyz + dx^2 + 2exy + fy^2$: it is then easy to establish the identical relations

$$m^2 - 2bm + d = 0,$$
$$mn + nm - 2bn - 2cm + 2e = 0,$$
$$n^2 - 2cn + f = 0.$$

It hence easily appears that any given function of m, n can, by aid of the five parameters b, c, d, e, f, be expressed in the form $A + Bm + Cn + Dmn$.

This form containing 4 arbitrary constants, it follows that in general any given matrix of the second order can be expressed as a function of m and n; for there will be four linear equations between A, B, C, D and the four elements of the given matrix. But this statement is subject to two cases of exception.

The first of these is when n and m are functions of one another: for in this case $A + Bm + Cn + Dmn$ is reducible to the form $P + Qm$, and there will be only two disposable constants wherewith to satisfy the four linear equations.

The second case is when the determinant of the fourth order formed by the elements of the four matrices $\begin{vmatrix} 1, m \\ n, mn \end{vmatrix}$ vanishes; writing $m, n = \begin{vmatrix} t_1, t_2 \\ t_3, t_4 \end{vmatrix}, \begin{vmatrix} \tau_1, \tau_2 \\ \tau_3, \tau_4 \end{vmatrix}$ respectively, it is not difficult to show that the value of this determinant is

$$= (t_2\tau_3 - \tau_2 t_3)^2 + \{(t_1 - t_4)\,\tau_2 - (\tau_1 - \tau_4)\,t_2\}\{(t_1 - t_4)\,\tau_3 - (\tau_1 - \tau_4)\,t_3\}.$$

This expression is a function of the five parameters b, c, d, e, f, as may be shown in a variety of ways.

Thus it is susceptible of easy proof that if μ_1, μ_2 are the roots of the equation $\mu^2 - 2b\mu + d = 0$, and ν_1, ν_2 the roots of the equation $\nu^2 - 2d\nu + f$, then, the two matrices being related as above, we must have $\begin{matrix}(m - \mu_1)\ (n - \nu_1) = 0 \\ (m - \mu_2)\ (n - \nu_2) = 0\end{matrix}$, and consequently, by virtue of the middle one of the three identities, $\mu_1\nu_1 + \mu_2\nu_2 - 2e = 0$. Writing this in the form

$$(\mu_1\nu_1 + \mu_2\nu_2 - 2e)\ (\mu_1\nu_2 + \mu_2\nu_1 - 2e) = 0,$$

this is

$$4e^2 - 2e\,.\,4bc + (\mu_1{}^2 + \mu_2{}^2)\ (\nu_1{}^2 + \nu_2{}^2) + 2\,\mu_1\mu_2\nu_1\nu_2 = 0,$$

which gives

$$e^2 - 2bce + b^2f + c^2d - df = 0;$$

the function on the left hand is the invariant (discriminant) of the ternary quantic appurtenant to the corpus, and we have this invariant $= 0$ as the necessary and sufficient condition of the involution of the elements of the corpus; the invariant in question is for this reason called the involutant.

Expressing the values of the coefficients in terms of the elements of the two matrices, viz.

$$2b = t_1 + t_4, \qquad 2c = \tau_1 + \tau_4,$$
$$d = t_1t_4 - t_2t_3, \qquad 2e = t_1\tau_4 + \tau_1t_4 - t_2\tau_3 - t_3\tau_2, \qquad f = \tau_1\tau_4 - \tau_2\tau_3,$$

it at once appears that the two expressions for the involutant are, to a numerical factor *près*, identical.

It can be shown *à priori* that the involutant of a corpus of the second order must be expressible in terms of the coefficients of the function; and therefore, being obviously invariantive in regard to linear substitutions impressed on m, n, it must be also invariantive for linear substitutions impressed on z, x, y, and must therefore be the invariant of the function. The corresponding theorem is not true, it should be observed, for the involutant of a corpus beyond the second order; for such involutant cannot in general be expressed in terms of the coefficients of the function.

The expression for the involutant in terms of the t's and τ's may also be obtained directly from the equation $(m - \mu_1)\ (n - \nu_1) = 0$. To this end it is only necessary to single out any term of the matrix represented by the left-hand side of the equation and equate it to zero: the resulting equation rationalised will be found to reproduce the expression in question.

I have thus indicated four methods of obtaining the involutant to a matrix-corpus of the second order; but there is yet a fifth, the simplest of all, and the most suggestive of the course to be pursued in investigating the higher order of involutants.

I observe that for a corpus of any order the function $mn - nm$ is invariantive for any linear substitution impressed on m and n. Its determinant will therefore be an invariant for any substitution impressed on m and n. When m and n are of the second order, reducing each term of $(mn - nm)^2$, i.e. $mnmn - mn^2m - nm^2n + nmnm$, and of $mn - nm$, by means of the three identical equations to the form of a linear function of mn, m, n, 1, it will be found without difficulty that there results the identical equation $(mn - nm)^2 + I = 0$, the coefficient of $mn - nm$ vanishing. Consequently the determinant of the matrix $mn - nm$ is equal to I, which on calculation will be found to be identical with the invariant of the ternary quadric function.

It is obvious from the three identical equations that if m, n are in involution—that is, if their involutant is zero—every rational and integral function of m, n will be in involution with every other rational and integral function of m, n. Hence follows this new and striking theorem concerning matrices of the second order: If $f(m, n)$ and $\phi\ (m, n)$ are any rational functions whatever of m, n, the determinant to the matrix $mn - nm$ is contained as a factor in the determinant to the matrix $f\phi - \phi f$.

[It may be noticed that f, ϕ need not be integer functions *by stipulation*, because any linear function of mn, m, n, 1, divided anteriorly or posteriorly by a second like function, can itself be expressed as a linear function of the same four terms.]

As a very simple example of the theorem, observe that the determinant of $m^2n - mnm$ will contain as a factor the determinant of $mn - nm$.

3. *On a Modification of Bunsen's Ice Calorimeter. By* Professor BALFOUR STEWART, *F.R.S.*

This instrument was exhibited to the Section. It was designed in order to obviate the experimental difficulties attending the use of Bunsen's calorimeter. In it the tube containing water is retained as the essential part of the instrument, but instead of being fused into an outer vessel filled with ice it is fused into the bulb of a large spherical mercurial thermometer, after the manner of Favre and Silbermann, so that while the inside contains water the outside is in contact with the mercury of the thermometer. The whole thermometer-bulb is inclosed in a copper envelope, which surrounds it without contact, and this copper envelope is kept at 0° C. by being surrounded with melting ice. Under these circumstances the temperature of the thermometer will also be at 0° C. This temperature is recorded by a very open scale, so that a small rise may be easily seen. The experiment is made as follows:—After the whole has been surrounded sufficiently long with melting ice, the substance whose specific heat we wish to find is dropped into the ice-cold water of the tube. Its heat is then rapidly communicated, first to the water, and from it through the glass of the tube to the mercury of the thermometer, and the rise of temperature of the latter is recorded on its stem. Theoretically a slight correction has to be made for the heat which is given out during the progress of the experiment by the (now) heated thermometer to the copper envelope which surrounds it; but in practice this may be disregarded, and the instrument is found to give us a rapid and sufficiently accurate method of determining the specific heat of such substances as can only be procured in small quantity. In using the instrument it is desirable to have a small quantity of mercury at the bottom of the water in the glass tube, by which means the heat is more rapidly communicated.

4. *On some Measurements of Glacier-Motion in* 1883. *By* Professor ARTHUR SCHUSTER, *F.R.S.*

A change has once more taken place in the general motion of Swiss glaciers, for they are again pushing forward into the valleys. For a year or two it had been noticed that their upper ends increased in bulk, and now there is no doubt about the steady advance. The author's personal information has been gained in the Chamonix valley, but the reports from different parts of Switzerland seem all to

agree, and even the Rosenlaui Glacier, which a few years ago seemed doomed to total annihilation, is recovering and increasing. That the general advance will not remain without its exceptions is more than probable from previous experience. He is speaking only about the majority of glaciers in the western Alps, for he has heard nothing as to the behaviour of the ice in the Engadine or in the Tyrol.

It was generally said in Chamonix, during this last summer, that the lower end of the Glacier des Bossons came forward at the rate of one metre a week. He went on Wednesday, July 11, to mark some rocks at the base of the glacier, which was then melting rapidly, in order to see whether the downward motion really overbalanced the decrease by fusion. The eastern side of the glacier rested against a large boulder, while at the western end only loose stones covered the ground in front of the ice. He returned on Monday, the 23rd, and noted the following change: The eastern end rested still against the same boulder, covering it exactly to the same spot as before; and so unchanged did this side appear that one might have imagined it was the same ice that formed the end of the glacier. The ice which had melted against the rock was replaced by the advancing glacier, but no change in the position of the front could be seen. Not so on the western side. Here a thick tongue of ice projected from the glacier, and reached over one metre further down the valley than the former limit of the glacier.

Here we have, then, in the middle of summer an actual advance of the glacier, which, though not so large as reported, is yet already sufficiently important, and will be still more so as the season advances and the melting takes place less rapidly.

The weather during the interval between his two visits had, with the exception of two hot days, been rainy and bad, but it was never exceptionally cold.

He also took some rough sights to see whether the level of the glacier at the point where tourists generally cross it is rising or not, but it seemed, if anything, to be lower on his second visit than on his first.

It seemed interesting, on account of this forward motion of the lower end of glaciers, to study once more their daily rate of descent. As glaciers flow down the valleys, and melt away on their surface and front, they will appear to advance or to retreat, according as the gain by daily downward motion overbalances or not the loss by melting. It seemed, therefore, probable that the daily motion was more rapid now than it had been while the glaciers were retreating, and this seemed only a consequence of the fact that the upper ends of the glaciers were generally acknowledged to be much higher and bulkier than of late years. The author's results do not, as will appear, allow us to draw any very certain inference on that point; but the cause of this uncertainty is worth relating.

He undertook to make a series of measurements on stakes placed along an approximately straight line across the Mer de Glace, a little higher up than the Montanvert. The theodolite was firmly placed on shore. Measurements were taken on the morning and afternoon of July 21, on July 24 and 25. They revealed an irregularity of motion which has not, to his knowledge, been previously observed.

To Forbes we owe the first series of accurate measurements, and the following quotation will show that his observations pointed to a very regular advance of the glacier:[1]

'(5) When we compare the motion of a given point of a glacier any day of one year and the same day of another, the probability is that the velocity will be exactly the same, if the season be equally hot or cold; hence, surely, a most unexpected result, which I first announced in 1842, that *a few days' observation of a glacier will enable anyone to compare its mean rate of motion over its various parts and with different glaciers.* Thus the motion of a point marked D2 on the Mer de Glace was, in 1842 from August 1 to August 9, 16½ inches daily; from August 9 to September 16, 18 inches. Now next year, 1843, one observation gave 16 inches, and in 1844 one observation in September gave 17½ inches. But still further (6), the very law of flexure of the ice is the same from year to year; a

[1] *Phil. Trans.* 1846, p. 177; *Theory of Glaciers*, p. 149.

series of stations across the ice at the Montanvert gave, in 1842, the following (simultaneous) relative velocities:—

1·000 1·332 1·356 1·367.

The same points being recovered in 1844, the relative motions were (by a single observation of the space moved over in five days):—

1·000 1·339 1·362 1·374;

ratios almost the same, but slightly increasing, which corresponds with the fact mentioned above (3), that when the absolute velocities are greater the relative velocities are so too, which was here the case, for the velocity denoted by 1·000 was a little greater in the second case than in the first.'

Professor Tyndall, who in many ways extended Forbes's observations, has such faith in the regularity of that motion that in all his researches he assumes it as an invariable fact which does not require any further testing, for, according to the published accounts, the daily motion seems, with one exception, to be always obtained from a single set of measurements. But Tyndall also noted a sudden motion of a few inches at one place; and if such sudden disturbances do take place, it is evidently better to obtain the average daily motion from observations taken as close together as possible, as only then would these sudden slips be eliminated.

The author's observations are not favourable to great regularity of glacier-motion, but in bringing them forward he is well aware of the great evidence on the other side, and he therefore gives them only as an example that great irregularities may occasionally take place.

He gives in a table the average hourly motion in centimetres in the different stakes between July 21, 24, and 25 respectively:—

Hourly Motion in Centimetres.

Stake:	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Between July 21, 3 P.M., and July 24, 1 P.M.	1·1	1·1	1·4	1·1	1·3	1·3	1·2	0·6
Between July 24, 1 P.M., and July 25, 8 A.M.	1·0	1·5	1·6	2·5	2·2	1·9	4·1	5·5
Total average between July 21, 3 P.M., and July 25, 8 A.M.	1·1	1·1	1·4	1·4	1·5	1·4	1·8	1·6

The first stake was placed about 70 metres from the western end of the glacier, the successive distances to the other stakes being in metres 47, 53, 26, 29, 48, 47, 92. The last stake was just within the eastern moraine.

A glance at the table will show that the glacier-motion during the first three days of observation was much less rapid than during the last, and this is especially striking on the eastern side, where the last stake had actually moved during the last nineteen hours two and a half times further than during the previous seventy hours, the hourly motion being nine times as large in the second period. The relative motion between the eastern and western ends was preserved during the time over which the observation extended. At first it was the western end which moved more quickly, but during the last days the eastern end followed so rapidly that the total average for the four days shows a greater movement of the eastern side.

It is needful to add a word as to the accuracy of these numbers, as the author would not wish to press them against the much more extended series of measurements given by Forbes and Tyndall, unless he felt pretty sure that they fairly well presented the actual motion of the glacier during the period of observation. He may say at once that he does not pretend to rival the accuracy of former observers. His instrument was only divided to minutes, but the errors of setting were much smaller, and half-minutes could easily be estimated. Nevertheless he will assume that an error of one minute has actually been made; this would imply an error of about 5 centimetres for the first stake and less than 15 for the last. In the most

unfavourable case we might therefore have for the hourly motion of the last stake in the two periods 1 and 3·9 centimetres instead of 0·6 and 5·5; that is, we should still have to deal with an hourly motion nearly four times as great at one time as at another. But the whole run of the observations shows that none but systematic errors could account for the discrepancy, and he has endeavoured to avoid such systematic errors by choosing two fixed points of reference, one of which should be nearly in a line with the stakes and the other as nearly at right angles to it as possible. In the actual case the angular distance between the two first points was about 113°. The regular and consistent agreement between measurements of that distance on different days is, he thinks, a fair test of the absence of systematic errors. He need not here allude to the other and obvious precautions to be taken in the setting up and levelling of a theodolite. The stakes were not planted sufficiently deep into the ice, and were often found inclined out of the vertical or even removed from their proper place. They had been planted near the ordinary tourist-track across the glacier, and were apparently considered by some of them to be placed there for their special benefit, to be taken out and used as alpenstocks. Two of them disappeared in this way, but the holes in which they had stood could always be recovered, and as the point of the stick sighted was always its junction with the ice, and as the sticks were always placed vertical with a plumb-line before each measurement, no appreciable error is due to any displacement of the sticks.

The author considers, however, that the best confirmation of the results of the measurements is to be found in the fact that, independently of the theodolite, he could trace that same irregularity by simply looking along the line of sticks from convenient positions.

The stakes had been planted already on July 18, and he could, without taking any measurements, see that even from that date up to the 21st the eastern side of the glacier had advanced very little on the eastern side compared to the western, while on the last day the sticks seemed to be again much more in a straight line than they had previously been. The eastern moraine near the place where the eighth stick was placed showed signs of disturbance during the night of July 23–24, which had been stormy, snow having fallen considerably below the Montanvert.

It is not easy to compare the average motion of the glacier with that of previous observers, because the rate of motion seems to vary considerably with the place across which the stakes are placed.

When Forbes measured the glaciers were advancing, and the rate of motion seems to have been increasing between the years 1842 and 1846 (p. 189); the motion opposite the Montanvert seems to have been at the rate of about 2 feet a day, or about 2·5 centimetres an hour, and was therefore about as large, probably a little larger, than during the night of July 24–25 of the present year, considerably larger, however, than during the period July 21–25.

Professor Tyndall made a series of observations on the Mer de Glace in the year 1858;[1] the place chosen for the author's measurements coincides approximately with his line BB[1]. His measurements give 7 inches on the western side and a gradual increase to 26 inches on the east; the hourly motion would therefore vary from about 0·7 to about 2·7 centimetres; the relative motion of east and west is not very far different from that observed during the last night's observation; the total motion seems a little smaller than during that night, but in the view of the altogether different result arrived at this year during the period July 21–24 no trustworthy comparison can be established. Professor Tyndall has kindly informed the author that, according to his recollection, the Mer de Glace was already retreating when he made his observation. By comparing the author's measurements with his, it would seem that during the first period some cause prevented the regular motion of the eastern side of the glacier, which cause gave way on July 24, and during the ensuing night the relative motion of the eastern and western sides came into good agreement with that previously observed by Professor Tyndall.

It is much to be desired that further measurements should be undertaken, in order

[1] *Phil. Trans.* 1859, p. 262.

to see whether the irregularities found by the author in the glacier-motion are of frequent occurrence, or whether they are due to some special disturbing influences.

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5. *Note on some recent Astronomical Experiments at High Elevations in the Andes. By* Ralph Copeland, *Ph.D.*

In the earlier part of the paper the author narrates the circumstances which led him to undertake these experiments on his return from an expedition to observe the last transit of Venus, and the exceptional difficulties encountered, owing to the season of the year and the state of affairs in northern South America. He also expresses his obligation to Lord Crawford for the loan of instruments and other help, and to the Royal Mail Steam Packet, the Panama Railway, and to the Pacific Steam Navigation Companies for liberal aid, and especially to Mr. Thorndike, lessee of the remarkable railway which, starting from Mollendo, on the Pacific, crosses the Western Andes at a height of 14,666 feet, terminating at Puno, on Lake Titicaca, 12,505 feet. On arriving at Vincocaya (14,360 feet), the loftiest station on this line, the author found that the weather was so unsettled that he went on with some of the lighter instruments to La Paz, in Bolivia (12,050 feet). His experiences are thus narrated.

'La Paz being on the second chain of the Andes from the coast, the weather there was not nearly so bad as at Vincocaya. Unfortunately it was full moon, so that I had not a very good chance of testing the purity of the air, but on the night of February 21, when the moon was almost exactly full, and at the same altitude, but more than 90° from the constellation of the Bull, I made a naked-eye sketch of the Hyades and Pleiades. In the Pleiades I distinctly made out ten stars, D.M. + 24°, 553 and 556, which are both 7·0 mag., being seen as one star, and D.M. + 24°, 546, of 6·3 mag., being clearly visible. In the head of Taurus I made out seventeen stars, two of which, D.M. + 16°, 586 and 605, resp. 6·0 and 5·0 mag., are not in Argelander's "Uranometria Nova," which is supposed to contain all stars seen by an average eye in Central Europe. σ Tauri was also easily seen to be double. All this was very promising.

'Thinking I might now venture on giving Vincocaya a regular trial, with my 6-inch telescope mounted on an extempore stand, and expecting by this time to meet my more complete apparatus, I returned thither, arriving on the last day of February. I stayed there seventeen days, but almost all that time the weather was terribly unsettled. The late mornings were, indeed, fairly sunny, but the air was filled with visible exhalations from the sloppy pampa, which gradually thickened into dense clouds by shortly after noon; then came a tremendous thunderstorm, that lasted until dark. This storm poured down first showers of hail, and then torrents of rain that gradually changed into snow as night came on. The nights were almost absolutely overcast, but in the morning came a short interval of bright sunshine, as already mentioned, that rapidly melted the accumulated snow, and so formed the thunder-clouds which broke in the afternoon. A few glimpses of stars in the night showed good images, and gave hopes of what might be done when the season of "tempestades" had passed. I afterwards found that this was the usual character of the weather from the middle of December until the end of March. As a matter of fact the last storm of thunder and rain occurred at Vincocaya on March 31. Tired of inactivity, I descended to Puno, on the western shore of Lake Titicaca, on March 17. Here I remounted my telescope at a height of 12,540 feet above the sea. At first the weather was little better than on the more elevated pampas; however it gradually cleared up, and I was able to observe in a more or less regular way with the incomplete apparatus at my disposal. I shortly afterwards learnt that considerable difficulties had arisen as to the propriety of forwarding the remaining parts of my instruments to me through the Chilian lines, and it even became necessary to refer the matter to the Chilian seat of Government at Santiago. Eventually every facility was granted, but as a matter of fact I did not receive my apparatus until June 2.

'In the meantime I had kept a kind of running meteorological journal, not tying

myself to regular hours of making the readings, but noting down the chief facts as often as practicable. When the moon was in the way I examined the brighter stars of the southern heavens for duplicity, and was rewarded by the discovery of several very close pairs that had escaped Sir John Herschel and other observers—e.g. β Muscæ and H Velorum. On several evenings the definition was almost perfect with a power of 400. On the finest moonless nights I sketched the Milky Way, and with a very small direct-vision spectroscope of Dr. Vogel's arrangement I swept the southern part of the Milky Way on the plan advocated by Professor Pickering, and succeeded in finding a few minute planetary nebulæ and several members of a special class of stars with most remarkable spectra, of which γ Argûs may be taken as by far the most remarkable specimen. I feel almost sure that the spectrum of γ Argûs *must* have been observed at Melbourne or in India, although I have not met with a note to that effect.[1] I think that fully one-half of the light of this star is concentrated into four lines, three of which are close together in the neighbourhood of D, while the other is far away in W.L. 467, and is apparently identical with a line in the Stephan-Webb nebula, in the nebula near the north pole of the ecliptic, and also in G.C., No. 4,964. In the fainter specimens of this class, of which I found some five or six, the three yellow lines become merged into one, so that the spectrum apparently consists of two bright lines or bands, very far apart, and connected merely by a very feeble spectrum somewhat stronger in the middle of the space between these lines—a spectrum closely related to those of the Wolf-Rayet stars in the Swan.

'Both at Vincocaya and Puno I tried in various ways to get a view of the sun's corona or prominences without the spectroscope—for instance, by bringing the top of a telegraph-pole or the corner of a roof between the eye and the sun. I was astonished at the small degree of illumination of the atmosphere even in the immediate neighbourhood of the sun, but still I never could see any certain indication of the corona. I believe, however, that the experiment is well worth repeating, especially if photographs are taken even with an ordinary camera in place of merely trusting to the unaided sight. I also directed the telescope to the brighter stars and planets in the daytime, but without any special results, except that the images were somewhat brighter than at the sea-level. I never succeeded in seeing any other stars or planets except Venus near noonday, but Sirius and Jupiter were both plainly visible with the naked eye from a quarter to half an hour before sunset. Canopus, too, was plainly seen one minute before the sun's centre attained a zenith distance of 90°. Under fair conditions α Centauri and Mars might be added to the number of daylight objects, but there the list would probably end, unless an exceedingly elevated station were selected. I may add that nearly all the persons that I spoke to on the subject had frequently seen Venus with the naked eye in the daytime.

'This great transparency is associated with, and probably due in part to, the extreme dryness of the air. So dry, in fact, is the air that even the most extended hygrometrical tables do not suffice to reduce my observations satisfactorily. I can, therefore, at present only give the results for a specimen day or two—results calculated by Regnault's formulæ.

'*Monday, May* 7.

	A.M. 0·42	10·0	10·54	11·48	P.M. 12·18	1·12	4·18	P.M. 7·36
Tension in.	·083	·133	·123	·111	·114	·110	·122	·121
Percentage	41	31	27	24	25	23	37	54

'The direct solar radiation was also very intense. The black bulb thermometer I had with me contained in the glass covering a small amount of aqueous vapour, and was only graduated up to 205°, or rather only to 202° Fahr. as there was a negative correction of 3°. The tube ended a little higher up, without

[1] It was observed by Respighi, at Madras, and by Le Sueur; see Secchi, *Le Soleil*, German edition, Sect. 71. Note added Nov. 12, 1883.

a bulb of excess. On March 31, at 11.18, it indicated 201·5° Fahr., and was still rising. The shade temperature was about 62° Fahr., and the barometer stood at 18·7 in. The fine morning of May 24 gave, at 10.54 A.M., S.R. 191°. Dry bulb, 60·9°; wet, 48·2°. Barometer, 18·7 in. Tension, 0·232, or 43 %. This great dryness of the air causes an immense amount of evaporation from the surface of Lake Titicaca. The 4,400 square miles in area loses about 3 feet in depth, mainly by evaporation, or about $2\frac{1}{2}$ cubic miles of water, in the months May to December inclusive. At the driest season there is always more water running into it than out of it. On June 2, as I said before, I at last received my solar spectroscope and the remainder of my long-expected instruments. Wishing to give this apparatus the best possible chance, I immediately returned to Vincocaya, the highest point at my command, where the pressure of the air was about 1·2 in. less than at Puno. I did not, however, find the air appreciably clearer; what little was gained by the small decrease in density was about compensated by a slight dust-haze, resulting from the action of the regularly recurring afternoon breezes on the sandy pampa. To my great disappointment several prisms of my old-fashioned Browning solar spectroscope had been much damaged on the journey, so that its action on the sun was much impaired. The chief observed fact was the unmistakable increase of brightness towards the violet end of the spectrum. This was particularly shown by the facility with which the solar prominences could be observed in the Hγ, or 'near G' line. The prominences, in fact, could be seen with about equal ease in any of the four lines Hα, D_3, F, or Hγ; nor was a large dispersion at all as necessary as at the sea-level. The slit could also be opened *ad libitum*. The small spectroscope already spoken of, when used with a bit of cobalt glass, showed quite a range of lines above great H_2. At this station I completed the drawing of the southern part of the Milky Way, that I had begun at Puno. I also frequently viewed the zodiacal light with the small spectroscope, but although that light was so intense as to be visible when the moon had passed the first quarter I could never make out the faintest trace of lines in its spectrum. There was nothing more to be seen than a short continuous spectrum from just before E to a little beyond F. There, for the first time in my life, I saw the sun-spots by direct projection of the sun's rays through a small hole into a darkened room without the aid of any lens whatever. I was astonished what an amount of detail could be made out in this simple way. From Professor Peters, of Clinton, however, I found that this plan of viewing the solar spots was used fully two and a half centuries ago; indeed, a full account thereof is given in Scheiner's "Rosa Ursina." It is strange, indeed, that not a word of this, as far as I know, is to be found in any of our modern popular works on astronomy. On talking the matter over with Lord Crawford at Dunecht a few days ago, we tried this experiment, I may say at random, in one of the domes there, and immediately made out a spot by the help of an accidental hole in the roof. It will certainly be remarkable if it does not turn out that the sun-spots have been seen in this way long before the invention of the telescope. At Vincocaya, too, I again made a number of solar-radiation and other meteorological observations, of which I give the most striking ones, taken on a truly characteristic day. I was most comfortably quartered in the house of the genial and kind-hearted station-master. Round this house ran a wooden platform, on which, at daybreak, a family of goats capered and clattered about in the thin frosty air. At 6.30 A.M. the sky was intensely clear; the temperature, 7·1 Fahr.; the barometer, 17·4 in. At 7.48, the sun having of course risen, the thermometer had risen too, and showed 18·9°; the depression of the ice-covered thermometer was 3·0°, the tension 0·045 in., and the percentage of humidity was $43\frac{1}{2}$. By 8.5 these quantities had changed to 5·7° depr., 0·045 in. and 40 %; but the black-bulb thermometer already registered 107° (corrected), and the goats were actually basking in an air-temperature of 19·9°, or twelve degrees below the freezing point, and the fowls feeding; and now came a rapidly ascending series of sun-temperatures, $130\frac{1}{2}$, 137, $150\frac{1}{2}$, 154, 169, all within the fifty minutes from 8.10 to 9 A.M.; the sky excessively clear, Venus then about 11″ diameter, shining with an intense lustre in the dark blue air. At 9.36, when the black bulb was no less than 180°, the dry bulb was still 29·8°–30°, or 2° below the freezing point. At 1.56 the

S.R. was 201·6. At 2.25 occurred the strangest combination in my record, for with the dry bulb at the fairly comfortable range of 45·7° the wet bulb showed 30·6°, or was below the freezing point, and was accordingly coated with ice, while the black bulb showed 199·1°, or no less than 13° above 186·1°, the boiling point of water at Vincocaya. Respecting this same boiling point, perhaps I may be permitted to add a fact or two. An egg may be fairly lightly boiled in four and a half minutes, but twenty-four hours' boiling will not suffice to cook dried beans. During the construction of the railway, digesters were used for cooking this article of food, which is greatly in vogue in South America; but now that the digesters are worn out, beans can no longer be cooked at high altitudes. It is necessary to lengthen the chimneys of all the paraffin lamps by some six inches to get a flame devoid of smoke. It also takes a full hour longer to get up steam in a locomotive than at the sea-level. Of course temperature comes a little into play, but the diminution of air pressure is the main cause of these differences. A favourable chance of passing the blockade at all occurring unexpectedly, I left Vincocaya on June 27, and so had a mere glimpse of the sun, &c., at Arequipa on the 29th and 30th. S.R., 205½° to the very top of tube; tension, 0·139 in., 19·8 %. Now if we consider what is the best height and situation in which to place an observatory that it might be intended to maintain for a few years, I should recommend an elevation of some 9,000 to 12,000 ft. My own measures go to show that an increase of height of 150 ft. reduces the night temperature by about 1° Fahr. Now at 12,500 ft. on the clear nights there is almost always a certain amount of frost, so that for any greater altitude it is very easy to find the cold to which the observer would be exposed. It should be noted, too, that the cold is much more unpleasant to bear in a thin atmosphere than down at the sea-level. In a thin atmosphere, too, all exertion becomes fatiguing, and in particular that of moving about under a load of heavy garments. At considerable altitudes, I need hardly say, a given change of elevation affects the density of the air by only a comparatively small quantity—e.g. at Puno, as we have seen, the barometer stands at 18·7, for 12,540 ft. At Vincocaya we have 17·6, for 14,360 ft. At the lower station we have the potato cultivated in a hundred varieties, along with maize, &c., while at the upper one all horticulture is utterly impracticable, and barley even only yields a few green blades. This total change in the vegetable world is due to a decrease of mean temperature of about 13° Fahr. On the ground, therefore, of mere comfort and facility of work a station higher than Puno is not to be recommended for anything like permanent occupation. On the other hand it would be very valuable if a higher elevation could be commanded for a few months in the more favourable season, say from the beginning of October until the middle of December. At that season a station 18,500 ft. high might be occupied without serious inconvenience, and in Peru there would be the advantage of a practically vertical sun every day. This view is based on the fact that Dr. Falb and a gentleman whom I met repeatedly had spent several days on the summit of the Misti volcano (18,650 ft.) at the season just mentioned. I do not mean to say that the top of the Misti would be likely to be a good site, but in the neighbourhood of Puno, Santa Rosa, or of La Paz, or, in fact, almost anywhere in the neighbourhood of Lake Titicaca, a very favourable spot might be found for such an extra elevated station.'

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6. *On some points in Lemström's recent Auroral Experiments in Lapland. By* J. Rand Capron.

The existing sun-spot epoch augurs well for the advent of auroral displays in the coming winter, while the recent experiments of Prof. Lemström in Lapland have brought this interesting phenomenon prominently before the public mind. The author does not propose on this occasion to discuss the results of these experiments beyond pointing out that they can hardly be accepted in their present state as conclusive. Among the obscure points may be mentioned the want of any actual recorded measurement of the line considered to be recognised as the 'citron' auroral line; certain discrepancies which appear on comparing the discharges, or rather collections,

obtained from two sets of apparatus differing in size, but otherwise similar in construction, and on contrasting these with the currents registered by the galvanometer; and lastly and most importantly the absence of any comparisons of the so-called aurora-line with other spectra, for the purpose of elucidating the still obscure problem of the real nature of the auroral discharge, such discharge having hitherto proved not to accord with the spectrum of any artificial electric discharge yet produced. His object is rather to invite careful watch and look-out at the present time for auroral displays, in order that, so far as the less favourable conditions of this climate will permit, some at least of the conclusions arrived at by Prof. Lemström may be tested.

For the purpose it will be necessary for observers to employ—

1. A spectroscope of large field and low dispersion, but provided with some means for measuring the positions of the lines seen.

Owing to the faint character of the light obtained, the ordinary filar micrometer is not applicable, and both bright and dark points or lines, which are sometimes substituted for the micrometer wires, have each a disadvantage.

In fact, the approach of extraneous light (which is generally needed in such cases) during the primary examination of an auroral spectrum is undesirable.

On the whole the author thinks the simplest and best form of micrometer is obtained by the expedient of dividing the slit plate longitudinally into two halves, and making the upper half traverse the lower by a suitable micrometer movement.

In this way no artificial illumination of the field is resorted to, the citron line, the brightest of the group, being used to measure the fainter ones, the position of this in the lower spectrum being previously arrived at and indicated by a dark fixed point or index.

2. A galvanometer and pointed collecting apparatus should be employed, which may follow the lines of Professor Angström's apparatus, as recently described in 'Nature,' so far as the circumstances of the locality and its surroundings will permit.

3. To this latter it would be desirable to add some form of Professor Thomson's quadrant, or portable electrometer, for the examination of the condition of atmospheric electricity pending the discharges.

4. Some simple form of auroral transit instrument for obtaining heights and parallaxes of beams and arches, so that another big floating beam may not again catch observers unprepared, as in November last, and leave them with a good deal of guess-work as to altitudes and compass-points.

Lastly, whether the aurora examined be one ranging freely above, or one, so to speak, held captive by a 'streaming' apparatus, it is most necessary to obtain direct comparisons of its spectrum (after first securing as close position-measurements of the lines seen as may be) with other spectra of an appropriate nature. It is not possible in the short limits of this paper to indicate the direction of these comparisons.

As they have so signally failed in result hitherto, a wide field is still open for experiment; and if anything like a permanent auroral display can be secured by the electrician, upon the chemist will then fall the task of finding a spectrum which will aptly compare with it. If an aurora can be truly brought down to the earth's habitable surface, unattainable conditions of pressure and temperature can no longer be set up as excuses for failure, and it should be strange if the spectrum of the aurora remains much longer a mystery and a puzzle.

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7. *On some Indefinite Integrals, that contain the Elliptic Integrals* E *and* F. *By* Dr. D. Bierens de Haan.

In a Memoir in the Transactions of the Amsterdam Academy of Sciences, 'An Appendix to the Tables of Indefinite Integrals,'[1] the author gave the reduction-formulæ for the general indefinite integrals

[1] *Verhandl. Koninkl. Akad. Wetenschap.*, Vol. xxii. (1883).

$$\int \sin^p x \,.\, F dx, \qquad \int \cos^p x \,.\, F dx, \qquad \int \tan^p x \,.\, F dx,$$

and for some others of similar forms; also some that contain the denominator Δ, Δ^2, Δ^3. He did the same for another class that had the E instead of the F.

For each of these formulæ he gave the initial integrals for $p=1, 2, 3$, etc.

From these integrals, again, he deduced some other general ones with the factors F^2, E^2, EF; also with the initial cases.

In obtaining these reductions it was for some initial values necessary to admit certain new transcendents.

Now from the last-mentioned integrals, it is sometimes possible to eliminate these transcendents, and so obtain some new results, viz.:

$$\int F^2 \cos 2x \frac{dx}{\sin^3 x} = 2L \tan \tfrac{1}{2}x - \frac{2\Delta}{\sin x} F - \frac{\cos x}{\sin^2 x} F^2,$$

$$\int F^2 \cos 2x . dx = \frac{2}{k^2}(\Delta F - x) + \sin x \cos x . F^2,$$

$$\int F^2 \cos 2x \frac{dx}{\cos^3 x} = \frac{2}{1-k^2}\left\{\frac{\Delta}{\cos x} F - L \tan\left(\frac{\pi}{4} + \tfrac{1}{2}x\right)\right\} - \frac{\sin x}{\cos x} F^2,$$

$$\int E^2 \cos 2x . dx = \frac{1}{12k^2}\{[12E^2 - 3(1-k^2) - 2\Delta^2]k^2 \sin x \cos x - 8\Delta^3 E - (8 - 8k^2 + 3k^4)x\},$$

$$\int EF \cos 2x . dx = \frac{1}{3k^2}\{(\Delta^2 F + 3E)\Delta - (2-k^2)2x - (2 - 3EF)k^2 \sin x \cos x\}.$$

In order to obtain the general reduction-formulæ for these last results, it is necessary to put $p+2$ for p in the theorems lxxiii., lxxv., lxxv.^{a}, lxxvii.; to multiply with 2, and take the difference between this result and the original one. Then by consecutively substituting the relation $2 \sin^{p+2} x = \sin^p x(1 - \cos 2x)$, it follows that

$$\begin{aligned}\int \sin^p x \cos 2x . F^2 dx = \frac{1}{(p+1)(p+2)2k^2}\Big[&2p^2(1+k^2)\int \sin^{p-2} x \cos 2x . F^2 dx \\ &- \{2(p-1)(p-2) - (2p-1)k^2\}\int \sin^{p-4} x \cos 2x . F^2 dx \\ &+ \{4(p-2) - (2p-1)k^2\}\int \sin^{p-4} x . F^2 dx \\ &+ 4\int \sin^{p-2} x \cos 2x . dx - 4 \sin^{p-2} x \cos 2x . \Delta b \\ &- \{(1 - p\Delta^2)\cos 2x - (1 + 2\sin^2 x)\Delta^2\} 2 \sin^{p-3} x \cos x . F^2\Big] \quad . \text{ I.}\end{aligned}$$

$$\begin{aligned}\int \sin^p x \cos 2x . EF dx = \frac{1}{(p+2)(p+3)2k^2}\Big[&\{p + (p+2)k^2\}2p \int \sin^{p-2} x \cos 2x . EF dx \\ &- \{2(p-1)(p-2) + (2p-1)k^2\}\int \sin^{p-4} x \cos 2x . EF dx \\ &+ \{4(p-2) - (2p-1)k^2\}\int \sin^{p-4} x . EF dx \\ &+ 4\int \sin^{p-2} x \cos 2x . \Delta^2 dx + 4k^2 \int \sin^{p-2} x \cos 2x \cos x \frac{E}{\Delta} dx \\ &- (E + \Delta^2 F)\, 2 \sin^{p-2} x \cos 2x . \Delta \\ &- [(3 - p\Delta^2)\cos 2x - (1 - 6\sin^2 x)\Delta^2]\, 2 \sin^{p-3} x \cos x . EF\Big] \quad . \text{ II.}\end{aligned}$$

$$= \frac{1}{(p+1)(p+2)2k^2}\Big[2p^2(1+k^2)\int \sin^{p-2}x \cos 2x.EFdx$$

$$-\{2(p-1)(p-2)-(2p-1)k^2\}\int \sin^{p-4}x \cos 2x.EFdx$$

$$+\{4(p-2)-(2p-1)k^2\}\int \sin^{p-4}x.EFdx + 4\int \sin^{p-2}x \cos 2x.\Delta^2 dx$$

$$-4k^2\int \sin^{p-2}x \cos 2x \cos x.\Delta F dx - (\Delta^2 k + E)2 \sin^{p-2}x \cos 2x.\Delta$$

$$-\{(1-p\Delta^2)\cos 2x - (1+2\sin^2 x)\Delta^2\}2 \sin^{p-3}x \cos x.EF\Big] \quad . \quad . \text{ III.}$$

$$\int \sin^p x \cos 2x.E^2 dx = \frac{1}{(p+2)(p+3)2k^2}\Big[\{p+(p+2)k^2\}2p\int \sin^{p-2}x \cos 2x.E^2 dx$$

$$-\{2(p-1)(p-2)-(2p-1)k^2\}\int \sin^{p-4}x \cos 2x.E^2 dx$$

$$+\{4(p-2)-(2p-1)k^2\}\int \sin^{p-4}x.E^2 dx + 4\int \sin^{p-2}x \cos 2x.\Delta^4 dx$$

$$-4 \sin^{p-2}x \cos 2x.\Delta^3$$

$$-\{(1-p\Delta^2)\cos 2x - (1-6\sin^2 x)\Delta^2\}2 \sin^{p-3}x \cos x.E^2. \quad . \text{ IV.}$$

In operating in the same manner with the reduction-formulæ lxxiv., lxxvi., lxxvi.^{a}, lxxviii., in the Memoir above referred to, the difference between the two should be taken the other way; while afterwards the relation

$$2 \cos^{r+2}x = \cos^r x(1+\cos 2x)$$

should be made use of. It thus appears that

$$\int \cos^p x \cos 2x.F^2 dx = \frac{1}{(p+1)(p+2)2k^2}\Big[-(1-2k^2)^2 p^2\int \cos^{p-2}x \cos 2x.F^2 dx$$

$$+\{2(p-1)(p-2)-(2p^2-8p+5)k^2\}\int \cos^{p-4}x \cos 2x.F^2 dx$$

$$+\{4(p-2)-(2p-7)k^2\}\int \cos^{p-4}x.F^2 dx - 4\int \cos^{p-2}x \cos 2x.dx$$

$$+2 \cos^{p-2}x \cos 2x.\Delta F$$

$$+\{(1-k^2-p\Delta^2)\cos 2x + (1+2\cos^2 x)\Delta^2\}2 \sin x \cos^{p-3}x F^2\Big] \quad . \text{ V.}$$

$$\int \cos^p x \cos 2x.EFdx = \frac{1}{(p+2)(p+3)2k^2}\Big[-\{p-2(p+1)k^2\}2p\int \cos^{p-2}x \cos 2x.EFdx$$

$$+\{2(p-1)(p-2)-(2p^2-8p+3)k^2\}\int \cos^{p-4}x \cos 2x.EFdx$$

$$+\{4(p-2)-(2p-9)k^2]\int \cos^{p-4}x.EFdx$$

$$-4\int \cos^{p-2}x \cos 2x\Delta^2 dx - 4k^2\int \sin x \cos^{p-1}x \cos 2x \frac{E}{\Delta}dx$$

$$+(E^2+\Delta^2 F)2 \cos^{p-2}x.\Delta$$

$$-[\{3(1-k^2)-p\Delta^2\}\cos 2x + (1-3\cos^2 x)\Delta^2]2 \sin x \cos^{p-3}x.EF\Big] \quad . \text{ VI.}$$

$$= \frac{1}{(p+1)(p+2)2k^2}\Big[-(1-2k^2)2p^2\int\cos^{p-2}x\cos 2x.EFdx$$

$$+\{2(p-1)(p-2)-(2p^2-8p+5)k^2\}\int\cos^{p-4}x\cos 2x.EFdx$$

$$+\{4(p-2)-(2p-7)k^2\}\int\cos^{p-4}x.EFdx+4\int\cos^{p-2}x.\Delta^2dx$$

$$+4k^2\int\sin x\cos^{p-1}x\cos 2x.F\Delta dx+(\Delta^2F+E)2\cos^{p-2}\cos 2x.\Delta$$

$$-\{(1-k^2-p\Delta^2)\cos 2x-(1+\cos^2 x)\Delta^2\}2\sin x\cos^{p-3}x.EF\Big]\ . \quad \text{VII.}$$

$$\int\cos^p x\cos 2x.E^2dx = \frac{1}{(p+2)(p+3)2k^2}\Big[-\{p-2(p+1)k^2\}2p\int\cos^{p-2}x\cos 2x.E^2dx$$

$$+\{2(p-1)(p-2)-(2p^2-8p+3)k^2\}\int\cos^{p-4}x\cos 2x.E^2dx$$

$$+\{4(p-2)-(2p-1)k^2\}\int\cos^{p-4}x.E^2dx$$

$$-4\int\cos^{p-2}x\cos 2x.\Delta^4dx+4\Delta^2E\cos^{p-2}x\cos 2x$$

$$-[3\{(1-k^2)-p\Delta^2\}\cos 2x+(1-3\cos^2 x)\Delta^2]\sin x\cos^{p-3}x.E^2\Big]\ \text{VIII.}$$

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8. *On the probable Explanation of the Effect of Oil in Calming Waves in a Storm.* *By* E. P. Culverwell.

When the surface of the sea has become quite smooth after a storm, it is very common for long rollers to break on a sand bar. If there be no wind and the sea be glassy, these will not break until quite close to the shore, even though the ordinary theory points to their breaking earlier, unless a force directed in the opposite direction to that of their motion be exerted on the wave. Such a force might be supplied by the wind; but if it rise in any direction the waves break much sooner. This effect is therefore due to some secondary effect produced by the wind's pressure, and not directly by the pressure itself: and it is to the ripples produced on the surface (which *disturb* the wave motion), that the speedy breaking is to be attributed. It is, however, a direct result of theory that the ripples depend on surface tension for their propagation, and cannot exist in large amount on the oiled surface. It is also evident that the hold of the wind on the wave is greatly decreased by the absence of ripples, and thus the oil acts both to prevent the wind having much effect on the surface, and also to prevent the motion of the water in the wave itself being such as to cause breaking. The amount of friction may perhaps sensibly influence the breaking, but definite experiments on this are still wanting.

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9. *On the Pressure of the Vapour of Mercury at the Ordinary Temperature.* *By* Professor McLeod, *F.R.S.*

At the last meeting of the Association Lord Rayleigh called attention to a paper that had appeared in the 'Annalen der Physik und Chemie' (N. F. xvi. 610), by Hagen, on the Pressure of Saturated Mercury Vapour at Low Temperatures. The pressures given for the ordinary atmospheric temperatures, although considerably less than those published by Regnault, appeared rather higher than some recent observations seemed to warrant.

A method of determining the vapour pressure at ordinary temperatures seems to have occurred to Mr. Crookes and the author almost simultaneously, and he much regrets that the absence of the former from the present meeting prevents the Association learning the results of his work. Mr. Crookes intended to try the experiment in vacuo, whereas the author thought of saturating air with mercury vapour; but both intended to determine the quantity of evaporated mercury by a chemical test.

A glass flask of about 1·9 litres capacity was employed for the experiment, and within it was supported, by a piece of string, a glass tube 14 mm. in diameter, and filled with freshly distilled mercury, the flask being closed by a greased glass plate. After standing at the temperature of the laboratory for about nine days, the mercury tube was removed and a small quantity of boiling nitric acid poured into the flask and left to stand for some time. The acid was next neutralised by ammonia, and after the fumes in the flask had disappeared, the liquid was washed out with water, acidulated with hydrochloric acid, and treated with sulphuretted hydrogen. A slight brown colouration resulted. Several standard solutions of mercury were then made and tested with sulphuretted hydrogen in the same manner. The liquid from the flask gave a deeper colour than the solution containing ·00006 grms. of mercury, and a lighter colour than that containing ·00012 grms. It may therefore be assumed that the flask contained about ·00009 grms. of mercury vapour.

Subsequently the same flask was used and a tube of mercury 24 mm. in diameter (or exposing nearly three times as much mercury surface as the first), suspended in it and allowed to stand for a month. Treated in a similar manner the colour was nearly the same (a little lighter if anything) as that produced by a solution containing ·00012 grms. of mercury. One litre of the air in the flask, therefore, contained $\frac{\cdot 00012}{1 \cdot 9} = \cdot 00006316$ grms. of mercury. As the theoretical weight of a litre of mercury vapour at 20° C, and the normal pressure is 8·3474 grms., the volume of the vapour in 1 litre of the air was $\frac{\cdot 00006316 \times 1000}{8 \cdot 3474} = \cdot 007566$ cubic centimetres or $\frac{1}{132160}$ of the total volume. The pressure of the mercury vapour was therefore $\frac{760}{132160} = \cdot 00574$ mm., whereas Hagen's number for 20° is ·021 mm.

It may be observed that this method might have been expected to give rather an excess than a defect of the quantity of mercury, in consequence of condensation of mercury on the sides of the flask, and although the experiment was of a somewhat rough character, it seems to show that Hagen's number is too high.

A paper has also been published by Hertz (*Ann. Phys. u. Chem.*, N. F. xvii. 193), in which he estimates the pressure of the vapour at 20° to be only ·0013 mm., or only about one-fifth as great as indicated by the foregoing experiments.

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10. *On the Imperfection of the Galvanometer as a Test of the Evanescence of a Transient Current. By* Professor Lord RAYLEIGH, *F.R.S.*

In certain electrical measurements a galvanometer is used to indicate whether or not the integral value of a current of short duration is zero. For example, in the method given in Maxwell's 'Electricity,' § 755, for comparing the coefficients of mutual induction, M, of two pairs of coils, the evanescence of the integral current through the galvanometer is made the test of the fulfilment of a certain relation between the coefficients of induction and the resistances. The two primary coils are joined up in simple circuit with a battery. The two secondaries are also connected together in such a way that the inductive electro-motive forces conspire, and two points, P, Q, one on each connector, are brought into contact with the galvanometer terminals. In special cases, as for instance when the two pairs of coils are similar, there is no current through the galvanometer, whatever may happen in the primary circuit; but in general the establishment or interruption of the primary current will cause a deflection of the galvanometer indicative of the integral value of the current passing. The method consists in adding inductionless-resistance coils to one or other of the secondaries until this current vanishes.

The required conditions are most readily obtained by supposing the galvanometer circuit broken, and inquiring into the value of the electro-motive force E between the points P and Q. The same current y flows in both secondaries, and if x be the primary current, the equations are—

$$N_1 \frac{dy}{dt} + M_1 \frac{dx}{dt} + Ry = E$$

$$N_2 \frac{dy}{dt} + M_2 \frac{dx}{dt} + Sy = -E$$

M_1, M_2, are the induction coefficients to be compared; R, S, the resistances of the two secondaries (with associated resistance coils); N_1, N_2, their coefficients of self-induction. Thus—

$$(M_1+M_2)\,E=(M_2N_1-M_1N_2)\frac{dy}{dt}+(M_2R-M_1S)\,y.$$

Since y begins from 0 and ends at 0, the integral electro-motive force vanishes if—

$$M_2R-M_1S=0.$$

If this condition is satisfied, there is no integral current through the galvanometer, and then the ratio of induction coefficients is known by the ratio of resistances.

In general, however, the evanescence of the integral current is obtained by the opposition of consecutive positive and negative parts, and even although the whole duration of the effect be but a small fraction of the time of vibration, the needle of the galvanometer will be disturbed in such a manner as to make it difficult to say whether or not the whole impulse acting upon it be zero. To obtain a satisfactory measurement it is necessary to secure at least an approximate fulfilment of the second condition required in order that the current may be zero throughout, viz.—

$$M_2N_1-M_1N_2=0.$$

In this there is no difficulty, as we can easily increase the defective self-induction by the addition of other coils, placed at a sufficient distance. The most convenient plan is to include two coils by the variation of the relative situation of which the self-induction can be adjusted. With moderate care the initial impulsive electromotive force, caused by a sudden variation of the primary current, and dependent only upon the induction coefficients, may be made so small that the needle shows no uneasiness when the other adjustment relative to the resistances is complete.

In March 1881 I attempted, in conjunction with Messrs. Glazebrook and Dodds, to carry out the plan above suggested for the comparison of two coefficients of mutual induction. No satisfactory result could be obtained in the ordinary method of working, the needle showing uneasiness whatever resistances were employed, so that it was impossible to fix upon any particular value as corresponding to a zero integral current. The addition of other coils to increase the self-induction of one of the secondaries was so far successful that the needle could be reduced to quietness, but calculation showed that the additional self-induction found to be necessary in experiment was much in excess of what the above theory would indicate. The explanation which afterwards suggested itself to me was that the anomalous effect was due to the conducting rings upon which some of the coils were wound, and whose presence complicates the otherwise simple theory. We verified this view by bringing a coil of wire into the neighbourhood of one of the principal coils, the behaviour of the galvanometer needle being very sensibly different according as the auxiliary coil was open or closed.

The kind of embarrassment to which measurements of this kind are subject is well illustrated by placing the galvanometer in a tertiary circuit, not directly influenced at all by the battery current in the primary. A pair of coils with double wires, such as are often used for large electro-magnets, is suitable for the experiment. One wire of the first coil is connected with the battery, and forms the primary circuit. The second wire of the first coil and the first wire of the second coil are connected, and constitute together the secondary circuit. The second wire of the second coil and the galvanometer form the tertiary circuit. The apparatus must be so adjusted that no effect is perceived at the galvanometer when the secondary is broken, whatever may happen in the primary. When this adjustment is complete the secondary is closed, and the effect is observed of opening or closing the primary. If the contacts are properly made, the integral current through the galvanometer at each operation is rigorously zero, but in the experiments that I have made no one could infer the fact from the behaviour of the galvanometer needle. The effect may be exaggerated by the insertion of a few iron wires into the induction coils.

11. *On the Adjustment of Numerical Results derived from Observation. By* T. B. SPRAGUE.

The author described the method he has employed in various investigations to obtain well-graduated tables from the data furnished by observations made on various bodies of lives. Among these may be specified investigations into the rate of mortality among recently selected lives, and into the rate of re-marriage among widowers, both of which are contained in the 'Journal of the Institute of Actuaries' (Laytons, London). However large the number of lives observed may be, the probabilities of marriage, death, &c. obtained for successive ages, never proceed with sufficient regularity; and it is always necessary to make use of some process of adjustment, in order to substitute for the observed series of ratios, a more regular one. The most satisfactory method, if practicable, would be to take a mathematical formula representing the law of progression, and to determine the values of the constants in it by means of the method of least squares. But even when we assume that the rate of death (or marriage) depends only on the age, it is not possible to obtain a formula that is suitable for all ages. Still more difficult would it be to find suitable formulas for the cases where the law depends on other circumstances besides age; thus, for instance, the rate of mortality among insured lives depends on the length of time that has elapsed since they were admitted; and the rate of marriage among widowers, depends not so much on their age, as on the length of time since they became widowers. Nothing has ever been done in the way of suggesting formulas to represent the rates of mortality and marriage in such cases.

In the absence of suitable formulas, some other method has to be adopted. One that has been very popular is the substitution for the irregular series of ratios given by observation, of a series deduced from it by a system of averages: for instance, instead of p_x, we may substitute $\frac{1}{2}(p_{x-1}+p_{x+1})$, or $\frac{1}{3}(p_{x-1}+p\ +p_{x+1})$, or $\frac{1}{4}(p_{x-1}+2p_x+p_{x+1})$. In practice many more terms are employed in calculating the average, say 15. This method lessens the irregularities of the original series, but does not get rid of them altogether. It is therefore not possible by the use of this method, whatever may be the particular formula employed, to get an adjusted series that proceeds with entire regularity. But there is a more serious objection to the method, namely, that it has a tendency to distort the law of the original figures, and to remove features of the progression that ought to be retained. If we suppose the method applied to a perfectly regular series, it should, if it is a theoretically correct method, leave the series unaltered. But it is easy to see that the series will be altered unless it follows a certain law, which is determined by solving the equation of differences,

$$p_x = A\,p_x + (B\,p_{x-1}+p_{x+1}) + C\,(p_{x-2}+p_{x+2}) + \ \ldots\ldots$$

obtained by equating the adjusted value, given by the formula, to the original value. If the series follows the law thus found, the method will leave it unaltered, but it will alter a series following any other law; and repeated application of the method would still further distort the law. For these reasons the method seems quite unsuitable for general adoption, if indeed it is ever thoroughly suitable.

The author has therefore employed a graphical method. Taking the age as the abscissa, the unadjusted ratios derived from the original observations are plotted down on a sheet of cross-ruled paper as ordinates. When this has been done carefully, it is always found that, notwithstanding the irregularities in the progression, which are sometimes very great, the general law of the progression becomes obvious. Joining the ends of successive ordinates, we get a broken line, the general course of which indicates the law, and we have then to substitute for this broken line a smooth curve which, on the whole, follows the same course. This smooth curve is drawn, either by hand, or by some mechanical means, such as the use of the 'French curves' sold by mathematical instrument makers; and the ordinates being read off, measured, or estimated, according to circumstances, give an adjusted series of figures. This has then to be tested by comparison with the original observations. The adjusted probability of death or marriage, &c. at each age, is multiplied into the number of lives under observation at that age, so as to get the calculated

number of deaths, marriages, &c. at every age. These are then added together and compared with the observed numbers of deaths, marriages, &c., and the deviations are noted. These indicate where our curve requires correction; for instance, they may indicate that for a certain range of ages, the ordinates require to be increased 5 per cent., and for other ages to be diminished 3 per cent. The corrections thus indicated are applied to the curve, and a fresh curve is drawn which will give effect to them as far as is possible without introducing irregularities. The ordinates of this second curve are then read off, and compared as before with the original observations, and the process repeated as often as may be found necessary.

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12. *On the Action of Currents of Air between Plates.* *By* PHILIP BRAHAM, *F.C.S.*

On investigating the cause of what is known as Faraday's experiment on the aspirating power of currents of air, I contrived an apparatus consisting of two metal plates 5 cm. diameter, to one of which a tube 4 mm. diameter is attached, and to the other a tube with a hole ·1 mm. The plates can be adjusted parallel to each other at any required distance, and also the plate with the small hole is movable parallel to its plane, the distance between centres of plates being measurable.

A current of air at constant pressure is forced between the plates from the larger tube, the smaller tube being connected with a pressure gauge.

A series of experiments (illustrated by curves submitted) showed that there are certain points at which the resultant vacuum area is greater than pressure, and others at which pressure is greater, showing that the phenomenon is due to a series of vibrations which are further apparent when higher pressure is employed.

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13. *A new Reflector for Incandescent Electric Lamps.* *By* Professor FRANK CLOWES, *D.Sc.*

Recent experiments have proved the practicability of a method recently proposed for securing complete or partial forward reflexion in any direction of the light emitted from the back of the incandescent filament of the lamp. The idea was conceived of attaching a metallic film to the exterior of the glass globe, this film being applied in any desired part, so as to secure reflexion from any portion of the surface, and also, if necessary, in so thin a form as to allow a certain amount of light to be transmitted, and a portion only reflected.

The films experimented upon thus far have been silver films deposited from an ammoniacal solution of silver tartrate. It has been found easy to produce these of any desired opacity by varying the strength of the solution; they have usually been protected from injury by coating them with varnish. Direct photometric measurement shows that a Swan lamp, after being silvered over half its surface, throws forward practically twice as much light as it did before being thus prepared. The skeleton-like appearance of the luminous filament is also removed by this method of reflexion.

The preliminary experiments thus far made seem to indicate that this method of applying the metallic film is cheap and easy, and there are manifest advantages in employing a metal with such high reflecting power as silver.

There are many applications of the lamp for which the reflector suggests itself; for the writing-table, billiard-table, and frequently for general illumination of rooms from wall-brackets, the opaque film seems appropriate, whilst in other cases a partially transparent film causes the larger part of the light to be thrown forward, whilst enough light is transmitted to sufficiently illuminate the space behind the lamp.

The convenience of having the reflector upon the lamp itself, and therefore requiring no separate attachment or support, will be evident.

Section B.—CHEMICAL SCIENCE.

President of the Section—J. H. Gladstone, Ph.D., F.R.S., V.P.C.S.

THURSDAY, SEPTEMBER 20.

The President delivered the following Address:—

A sectional address usually consists either of a review of the work done in the particular science during the past year, or of an exposition of some branch of that science to which the speaker has given more especial attention. I propose to follow the latter of these practices, and shall ask the indulgence of my brother chemists while I endeavour to place before them some thoughts on the subject of Elements.

Though theoretical and practical chemistry are now intertwined, with manifest advantage to each, they appear to have been far apart in their origin. Practical chemistry arose from the arts of life, the knowledge empirically and laboriously acquired by the miner and metallurgist, the potter and the glass-worker, the cook and the perfumer. Theoretical chemistry derived its origin from cosmogony. In the childhood of the human race the question was eagerly put, 'By what process were all things made?' and some of the answers given started the doctrine of elements. The earliest documentary evidence of the idea is probably contained in the Shoo King, the most esteemed of the Chinese classics for its antiquity. It is an historical work, and comprises a document of still more venerable age, called 'The Great Plan, with its Nine Divisions,' which purports to have been given by Heaven to the Great Yu, to teach him his royal duty and 'the proper virtues of the various relations.' Of course there are wide differences of opinion as to its date, but we can scarcely be wrong in considering it as older than Solomon's writings. The First Division of the Great Plan relates to the Five Elements. 'The first is named Water; the second, Fire; the third, Wood; the fourth, Metal; the fifth, Earth. The nature of water is to soak and descend; of fire, to blaze and ascend; of wood, to be crooked and to be straight; of metal, to obey and to change; while the virtue of the earth is seen in seed-sowing and ingathering. That which soaks and descends becomes salt; that which blazes and ascends becomes bitter; that which is crooked and straight becomes sour; that which obeys and changes becomes acrid; and from seed-sowing and ingathering comes sweetness.'[1]

A similar idea of five elements was also common among the Indian races, and is stated by Mr. Rodwell to have been in existence before the fifteenth century B.C., but, though the number is the same, the elements themselves are not identical with those of the ancient Chinese classic; thus, in the Institutes of Menu, the 'subtle ether' is spoken of as being the first created, from which, by transmutation, springs air, whence, by the operation of a change, rises light or fire; from this comes water, and from water is deposited earth. These five are curiously correlated with the five senses, and it is very evident that they are not looked upon as five independent material existences, but as derived from one another. This philosophy was accepted alike by Hindoos and Buddhists. It was largely extended

[1] Quoted from the translation by the Rev. Dr. Legge. In that most obscure classic, the *Yi-King*, fire and water, wind and thunder, the ocean and the mountains, appear to be recognised as the elements.

over Asia, and found its way into Europe. It is best known to us in the writings of the Greeks. Among these people, however, the elements were reduced to four—fire, air, earth, and water—though Aristotle endeavoured to restore the 'blue ether' to its position as the most subtle and divine of them all. It is true that the fifth element, or 'quinta essentia,' was frequently spoken of by the early chemists, though the idea attaching to it was somewhat changed, and the four elements continued to retain their place in popular apprehension, and still retain it even among many of the scholars who take degrees at our universities. The claim of wood to be considered an element seems never to have been recognised in the West, unless, indeed, we are to seek this origin for the choice of the word ὕλη to signify that original chaotic material out of which, according to Plato and his school, all things were created.[1] The idea also of a primal element, from which the others, and everything else, were originated, was common in Greece, the difficulty being to decide which of the four had the greatest claim to this honour. Thales, as is well known, in the sixth century B.C. affirmed that water was the first principle of things; but Anaximenes afterwards looked upon air, and Herakleitos upon fire as the primal element, while Pherekydes regarded the earth as the great ancestor. This notion of elements, however, was essentially distinct from our own. It was always associated with the idea of the genesis of matter rather than with its ultimate analysis, and the idea of *simple* as contrasted with *compound* bodies probably never entered into the thoughts of the contending philosophers.

The modern idea appears to have had a totally different origin, and we must again travel back to China. There, also in the sixth century B.C., the great philosopher Lao-tse was meditating on the mysteries of the world and the soul, and his disciples founded the religion of Taou. They were materialists; nevertheless they believed in a 'finer essence,' or spirit, that rises from matter, and may become a star; thus they held that the souls of the five elements, water, metal, fire, wood, and earth, arose and became the five planets. These speculations naturally led to a search after the sublimated essences of things, and the means by which this immortality might be secured. It seems that at the time of Tsin-she-hwang, the builder of the Great Wall, about two centuries before Christ, many romantic stories were current of immortal men inhabiting islands in the Pacific Ocean. It was supposed that in these magical islands was found the 'herb of immortality' growing, and that it gave them exemption from the lot of common mortals. The emperor determined to go in search of these islands, but some untoward event always prevented him.[2]

Some two or three centuries after this a Taouist, named Weipahyang, wrote a remarkable book called 'The Uniting Bond.' It contains a great deal about the changes of the heavenly bodies, and the mutual relation of Heaven and men; and then the author proceeds to explain some transformations of silver and water. About elixir he tells us, 'What is white when first obtained becomes red after manipulation on being formed into the elixir' ('tan,' meaning red or elixir). 'That substance, an inch in diameter, consists of the black and the white, that is, water and metal combined. It is older than heaven and earth. It is most honourable and excellent. Around it, like a wall, are the sides of the cauldron. It is closed up and sealed on every side, and carefully watched. The thoughts must be undisturbed, and the temper calm, and the hour of its perfection anxiously waited for. The false chemist passes through various operations in vain. He who is enlightened expels his evil passions, is delighted morning and night, forgets fame

[1] Students of the Apocrypha will remember the expression in the Book of Wisdom, xi. 17, 'ἡ παντοδύναμός σου χεὶρ καὶ κτίσασα τὸν κόσμον ἐξ ἀμόρφου ὕλης' ('Thy Almighty hand, that made the world of matter without form'). The same book contains two allusions to the ordinary elements, vii. 17 and xix. 18 to 20. The word στοιχεῖον is used in the New Testament only in a general sense (2 Pet. iii. 10), or in its more popular meaning of the first steps in knowledge.

[2] Nearly all my information in regard to this Taouist alchemy is derived from the writings of the Rev. Joseph Edkins, of Pekin, and the matter is treated in greater detail in an article on the 'Birth of Alchemy,' in the *Argonaut*, vol. iii. p. 1.

and wealth, comprehends the true objects of life, and gains supernatural powers. He cannot then be scorched by fire, nor drowned in water, &c. &c. . . . The cauldron is round like the full moon, and the stove beneath is shaped like the half-moon. The lead ore is symbolised by the White Tiger; and it, like metal amongst the elements, belongs to the West. Mercury resembles the sun, and forms itself into sparkling globes; it is symbolised by the Blue Dragon belonging to the East, and it is assigned to the element wood. Gold is imperishable. Fire does not injure its lustre. Like the sun and moon, it is unaffected by time. Therefore the elixir is called "the Golden Elixir." Life can be lengthened by eating the herb called Hu ma; how much more by taking the elixir, which is the essence of gold, the most imperishable of all things! The influence of the elixir, when partaken of, will extend to the four limbs; the countenance will become joyful; white hair will be turned black; new teeth will grow in the place of old ones, and age at once become youth. . . . Lead ore and mercury are the bases of the process by which the elixir is prepared; they are the hinge upon which the principles of light and darkness revolve.'

This description suggests the idea that the elixir of the Taouists was the red sulphide of mercury—vermilion—for the preparation of which the Chinese are still famous. That Weipahyang believed in his own philosophy is testified by a writer named Ko-hung, who, about a century afterwards, wrote the lives of celebrated Taouists. He tells how the philosopher, after preparing the elixir, took it, with his disciples, into a wood, and gave it first to his dog, then took it himself, and was followed by one of his pupils. They all three died, but, it appears, rose to life again, and to immortality. This brilliant example did not remain without imitators; indeed, two emperors of the Tang family are said to have died from partaking of the elixir. This circumstance diminished its popularity, and alchemy ceased to be practised in the Celestial Empire.

At the beginning of the seventh century the doctrine of Lao-tse was in great favour at the Chinese Court; learning was encouraged, and there was much enterprise. At the same time the disciples of Mahomed carried their arms and his doctrines over a large portion of Asia, and even to the Flowery Land. Throughout the eighth century there were frequent embassies between eastern and western Asia, wars with the Caliphs, and even a matrimonial alliance. We need not wonder, therefore, that the teachings of the Taouist alchemists penetrated westward to the Arabian philosophers. It was at this period that Yeber-Abou-Moussah-Djafer al-Sofé, commonly called Geber, a Sabæan of great knowledge, started what to the West was a new philosophy about the transmutation of metals, the Philosopher's Stone, and the Elixir of Life; and this teaching was couched in highly poetic language, mixed with astrology and accompanied by religious directions and rites. He held that all metals were composed of mercury, sulphur, and arsenic, in various proportions, and that the noblest metal could be procured only by a very lengthy purification. It was in the salts of gold and silver that he looked for the Universal Medicine. Geber himself was an experimental philosopher, and the belief in transmutation led to the acquirement of a considerable amount of chemical knowledge amongst the alchemists of Arabia and Europe. This gradually brought about a conviction that the three reputed elementary bodies, mercury, sulphur, and salt or acid, were not really the originators of all things. There was a transition period, during which the notion was itself suffering a transmutation. The idea became gradually clearer that all material bodies were made up of certain constituents, which could not be decomposed any further, and which, therefore, should be considered as elementary. The introduction of quantitative methods compelled the overthrow of mediæval chemistry, and led to the placing of the conception of simple and compound bodies upon the foundation of scientific fact. Lavoisier, perhaps, deserves the greatest credit in this matter, while the labours of the other great chemists of the eighteenth and the beginning of the nineteenth centuries were in a great measure directed to the analysis of every conceivable material, whether solid, liquid, or gaseous. These have resulted in the table of so-called elements, now nearly seventy in number, to which fresh additions are constantly being made.

Of this ever-growing list of elements not one has been resolved into simpler bodies for three-quarters of a century; and we, who are removed by two or three generations from the great builders of our science, are tempted to look upon these bodies as though they were really simple forms of matter, not only unresolved, but unresolvable. The notation we employ favours this view and stamps it upon our minds.

Is it, however, a fact that these reputed elements are really simple bodies? or, indeed, are they widely different in the nature of their constitution from those bodies which we know to be chemical compounds? Thus, to take a particular instance, are fluorine, chlorine, bromine, and iodine essentially distinct in their nature from the compound halogens, cyanogen, sulphocyanogen, ferricyanogen, &c.? Are the metals lithium, sodium, and potassium essentially distinct from such alkaline bases as ammonium, ethylamine, di-ethylamine, &c.? No philosophical chemist would probably venture to answer this question categorically with either 'yes' or 'no.' Let us endeavour to approach it from three different points of attack—(1) the evidence of the spectroscope, (2) certain peculiarities of the atomic weights, and (3) specific refraction.

1. *The Spectroscope.*—It was at first hoped that the spectroscope might throw much light upon the nature of elements, and might reveal a common constituent in two or more of them; thus, for instance, it was conceivable that the spectrum lines of bromine or iodine vapour might consist of the rays given by chlorine *plus* some others. All expectations of this have hitherto been disappointed: what we do frequently find is a certain similarity of character among the spectra of analogous elements, not rays of identically the same refrangibility. Yet, on the other hand, it must not be supposed that such a negative result disproves the compound nature of elements, for as investigation proceeds it becomes more and more clear that the spectrum of a compound is not made up of the spectra of its component parts.

Again, the multiplicity of rays given out by some elements, when heated, in a gaseous condition, such us iron, has been supposed to indicate a more complex constitution than in the case of those metals, such as magnesium, which give a more simple spectrum. Yet it is perfectly conceivable that this may be due to a complexity of arrangement of atoms all of the same kind.

Again, we have changes of a spectrum at different temperatures; new rays appear, others disappear; or even there occurs the very remarkable change from a fluted spectrum to one of sharp lines at irregular intervals, or to certain recurring groups of lines. This, in all probability, does arise from some redistribution, but it may be a redistribution in a molecular grouping of atoms of the same kind, and not a dissociation or rearrangement of dissimilar atoms.

A stronger argument has been derived from the revelations of the spectroscope in regard to the luminous atmospheres of the sun. There we can watch the effect of heat enormously transcending that of our hottest furnaces, and of movements compared with which our hurricanes and whirlwinds are the gentlest of zephyrs. Mr. Lockyer, in studying the prismatic spectra of the luminous prominences or spots of the sun, has frequently observed that on certain days certains lines, say of the iron spectrum, are non-existent, and on other days certain other lines disappear, and that in almost endless variety; and he has also remarked that occasionally certain lines of the iron spectrum will be crooked or displaced, thus showing the vapour to be in very rapid motion, while others are straight, and therefore comparatively at rest. Now, as a gas cannot be both at rest and in motion at the same time and the same place, it seems very clear that the two sets of lines must originate in two distinct layers of atmosphere, one above the other, and Mr. Lockyer's conclusion is that the iron molecule was dissociated by heat, and that its different constituents, on account of their different volatility, or some other cause, had floated away from one another. This seems to me the easiest explanation of the phenomenon; and, as dissociation by heat is a very common occurrence, there is no *a priori* improbability about it. But we are not shut up to it, for the different layers of atmosphere are certainly at different temperatures, and most probably of different composition. If they are of different temperatures the variations of the spectrum may only be an extreme case of what must be acknow-

ledged to be a fact by everyone more or less—that bodies emit, or cease to emit, different rays as their temperature increases, and notably when they pass from the liquid to the gaseous condition. And again, if the composition of the two layers of atmosphere be different, we have lately learnt how profoundly the admixture of a foreign substance will sometimes modify a luminous spectrum.

2. *Peculiarities of Atomic Weights.*—At the meeting of this Association at Ipswich, in 1851, M. Dumas showed that in several cases analogous elements form groups of three, the middle one of which has an atomic weight intermediate between those of the first and third, and that many of its physical and chemical properties are intermediate also. During the discussion upon his paper, and subsequently,[1] attention was drawn to the fact that this is not confined to groups of three, but that there exist many series of analogous elements having atomic weights which differ by certain increments, and that these increments are in most cases multiples of 8. Thus we have lithium, 7; sodium, 23, *i.e.* $7 + 16$; potassium, 39, *i.e.* $7 + (16 \times 2)$; and the more recently discovered rubidium, 85, *i.e.* $7 + (16 \times 5)$ nearly; and cæsium, 133, *i.e.* $7 + (16 \times 8)$ nearly. This is closely analogous to what we find in organic chemistry, where there are series of analogous bodies playing the part of metals, such as hydrogen, methyl, ethyl, &c., differing by an increment which has the atomic weight 14, and which we know to be CH_2. Again, there are elements with atomic weights nearly the same or nearly multiples of one another, instances of which are to be found in the great platinum group and the great cerium group.[2] This suggests the analogy of isomeric and polymeric bodies. There is also this remarkable circumstance: the various members of such a group as either of those just mentioned are found together at certain spots on the surface of the globe, and scarcely anywhere else. The chemist may be reminded of how in the dry distillation of some organic body he has obtained a mixture of polymerised hydrocarbons, and may perhaps be excused if he speculates whether in the process of formation of the platinum or the cerium group, however and whenever it took place, the different elements had been made from one another and imperfectly polymerised.

But this is not the largest generalisation in regard to the peculiarities of these atomic weights. Newlands showed that, by arranging the numbers in their order, the octaves presented remarkable similarities, and, on the same principle, Mendelejeff constructed his well-known table. I may remind you that in this table the atomic weights are arranged in horizontal and vertical series, those in the vertical series differing from one another, as a rule, by the before-mentioned multiples of 8—namely 16, 16, 24, 24, 24, 24, 32, 32—the elements being generally analogous in their atomicity and in other chemical characters. Attached to the elements are figures, representing various physical properties, and these in the horizontal series appear as periodic functions of the atomic weights. The table is incomplete, especially in its lower portions, but, with all its imperfections and irregularities, there can be no doubt that it expresses a great truth of nature. Now, if we were to interpolate the compound bodies which act like elements—methyl, 15; ammonium, 18; cyanogen, 26—into Mendelejeff's table, they would be utterly out of place, and would upset the order both of chemical analogy and of the periodicity of the physical properties.

3. *Specific Refraction.*—The specific refraction has been determined for a large majority of the elements, and is a very fundamental property, which belongs to them apparently in all their combinations, so long at least as the atomicity[3] is unchanged. If the figures representing this property be inserted into Mendelejeff's table, we find that in the vertical columns the figures almost invariably decrease as the atomic weights increase. If, however, we look along the horizontal columns, or better still if we plot the figures in the table by which Lothar Meyer has shown graphically that the molecular volume is a periodic function of the atomic weights,

[1] *Phil. Mag.*, May 1853.

[2] Another curious instance is the occurrence of nickel and cobalt in all meteoric irons, with occasionally chromium or manganese, the atomic weights and other properties of which are very similar.

[3] This exception includes not merely such changes as that from a ferrous to a ferric salt, but the different ways in which the carbon is combined in such bodies as ethene, benzene, and pyrene.

we shall see that they arrange themselves in a series of curves similar to but not at all coincident with his. The observations are not so complete or accurate as those of the molecular volumes, but they seem sufficient to establish the fact, while the points of the curves would appear to be, not the alkaline metals, as in Meyer's diagram, but hydrogen, phosphorus and sulphur, titanium and vanadium, selenium, antimony. Now, if we were to insert the specific refractions of cyanogen, ammonium, and methyl into this table, we should again show that it was an intrusion of strangers not in harmony with the family of elements.

But there is another argument to be derived from the action of light. The refraction equivalent of a compound body is the sum of the refraction equivalents of its compounds; and, if there is anything known for certain in the whole subject, it is that the refraction equivalent of an organic compound advances by the same quantity (7·6) for every increment of CH_2. If, therefore, the increment between the different members of a group of analogous elements, such as the alkaline metals, be of the same character, we may expect to find that there is a regular increase of the refraction equivalent for each addition of 16. But this is utterly at variance with fact: thus, in the instance above quoted, the refraction equivalent of lithium being 3·8, that of sodium is 4·8, of potassium 8·1, of rubidium 14·0, and of cæsium about 13·7. Neither does the law obtain in those series in which the increment is not a multiple of 8, as in the case of the halogens, where the increment of atomic weight is 45, and the refraction equivalents are chlorine 9·9, bromine 15·3, and iodine 24·5.

The refraction equivalents of isomeric bodies are generally identical; and the refraction equivalents of polymeric bodies are in proportion to their atomic weights. Among the groups of analogous elements of the same, or nearly the same, atomic weight we do find certain analogies: thus cobalt and nickel are respectively 10·8 and 10·4, while iron and manganese are respectively 12·0 and 12·2. But, as far as observation has gone at present, we have reason to conclude that, if metals stand to one another in the ratio of 2 : 1 in atomic weight, their refraction equivalents are much nearer together than that; while, on the other hand, the equivalent of sulphur, instead of being the double of that of oxygen, is at least five times as great.

The general tendency of these arguments is evidently to show that the elementary radicals are essentially different from the compound radicals, though their chemical functions are similar.

There remains still the hypothesis that there is a 'primordial element,' from which the others are derived by transmutation. With the sages of Asia it was the 'blue ether,' with Thales water, with Dr. Prout hydrogen. The earlier views have passed away, and the claims of hydrogen are being fought out by some of our ablest analysts on the battlefield of atomic weights and their rigorous determination.

There does not appear to be any argument which is fatal to the idea that two or more of our supposed elements may differ from one another rather in form than in substance, or even that the whole seventy are only modifications of a prime element; but chemical analogies seem wanting. The closest analogy would be if we could prepare two allotropic conditions of some body, such as phosphorus or cyanogen, which should carry their allotropism into all their respective compounds, no compound of the one form being capable of change into a compound of the other. Our present knowledge of allotropism, and of variations in atomicity, affords little, if any, promise of this.

The remarkable relations between the atomic weights of the elements, and many peculiarities of their grouping, force upon us the conviction that they are not separate bodies created without reference to one another, but that they have been originally fashioned, or have been built up from one another, according to some general plan. This plan we may hope gradually to understand better; but if we are ever to transform one of these supposed elements into another, or to split up one of them into two or three dissimilar forms of matter, it will probably be by the application of some method of analysis hitherto unknown.

Nothing can be of greater promise than the discovery of new methods of

research; hence I need make no apology to others who have lately done excellent work in chemistry if I single out the Bakerian Lecture of this year, by Mr. Crookes, on 'Radiant Matter Spectroscopy.' It relates to the prismatic analysis, not of the light transmitted or absorbed in the ordinary way by a solid or liquid, nor of that given out by incandescent gas, but the analysis of the fluorescence that manifests itself in certain bodies when they are exposed to an electric discharge in a highly exhausted vacuum. He describes, in an interesting and even amusing manner, his three years' quest after the origin of a certain citron band, which he observed in the spectrum of the fluorescence of many substances, till he was led into that wonderful labyrinth of uncertain elements which are found together in samarskite, and eventually he proved the appearance to be due to yttrium. As the test is an extremely delicate one, he has obtained evidence of the very general dissemination of that element, in very minute quantities—and not always very minute, for the polypes that built up a certain pink coral were evidently able to separate the earth from the sea water, as their calcareous secretion contained about ½ per cent. of yttrium. We have reason to hope that this is only the first instalment of discoveries to be made by this new method of research.

I cannot conclude without a reference to the brightening prospects of technical chemistry in this country. I do not allude to the progress of any particular industry, but to the increased facilities for the education of those engaged in the chemical manufactures. First as to the workpeople. Hitherto the young artisan has had little opportunity of learning at school what would be of the greatest service to him in his after career. The traditions of the Middle Ages were all in favour of literary culture for the upper classes, and the education suited for these has been retained in our schools for the sons of the people. It is true that some knowledge of common things has been given in the best schools, and the Education Department has lately encouraged the teaching of certain sciences in the upper standards. In the Mundella Code, however, which came into operation last year, 'elementary science' may receive a grant in all the classes of a boys' or girls' school, and in the suggested scheme there is mentioned simple lessons on 'the chemical and physical principles involved in one of the chief industries of England, among which Agriculture may be reckoned,' while 'Chemistry' is inserted among 'the specific subjects of instruction' that may be given to the older children. It is impossible, as yet, to form an estimate of the extent to which managers and teachers have availed themselves of this permission, for the examinations of her Majesty's inspectors under the new code have only just commenced; but one of the best of the Board schools in London has just passed satisfactorily in chemistry both with boys and girls. I trust that in those parts of the country where chemical industries prevail chemistry may be largely taken up in our elementary schools.

The great deficiency in our present educational arrangements is the want of the means of teaching a lad who has just left the common school the principles of that industry by which he is to earn his livelihood. The more purely scientific chemistry, however, may be learnt by him now in those evening classes which may be formed under the Education Department, as well as in those that have long been established under the Science and Art Department. The large amount of attention that is now being given to the subject of technical education is creating in our manufacturing centres many technical classes and colleges for students of older growth.

As to inventors, and the owners of our chemical factories, in addition to the Chemical Society and the Chemical Institute, there has recently been founded the Society of Chemical Industry. It came into existence with much promise of success; at the close of its second year it numbered 1,400 members; it has now powerful sections in London, Manchester, Liverpool, Newcastle, and Birmingham; and it diffuses information on technical subjects in a well-conducted monthly journal.

May the abstract science and its useful applications ever prove helpful to one another, and become more and more one chemistry for the benefit of mankind.

The following Papers were read:—

1. *On Sun-spots and the Chemical Elements in the Sun.* *By* Professors DEWAR *and* LIVEING.

The authors take as the text of this paper the spectroscopic observations of sun-spots made at Greenwich. They point out that it does not of necessity follow, because a spot is less luminous than the photosphere, that its temperature must be less, inasmuch as the radiation of short wave-length generally increases most rapidly with the increase of temperature; and the spectra of the vapours of some of the metals most abundant in the sun, such as iron and magnesium, are stronger in the ultra-violet than in the visible part of the spectrum. They remark that the unequal widening of the Fraunhofer lines in spots is analogous to the behaviour of terrestrial elements, which give lines of which some are far more readily expanded than others by increasing the density of the vapour. They show that there is little reason for supposing that the dark lines which are peculiar to spots are due to elements which are not to be found on the earth, because the spectra of our chemicals have as yet been very partially examined; and they have found in a cursory examination of the arc, while cerium and titanium are introduced into it, that a very great number of new lines make their appearance, of which some show coincidences with dark lines of spots too striking to be merely accidental. The disappearance of some Fraunhofer lines from spots they attribute, as others have done, to the emission of the upper regions of the sun's atmosphere balancing the absorption below; and they point out that the rays for which this happens are the rays which belong to vapour of small tension, corresponding to Mr. Lockyer's long lines—rays which should be emitted by the elements in their least complex state of aggregation. The singular ray with wave-length 4923, which is a line of iron of high vapour-tension, but behaves in the sun as a line of low vapour-tension, being frequently seen high up in the solar storms and disappearing from spots, they think must belong to some other metal as well as to iron. At the same time they point out that though the vapours in the upper regions of the solar atmosphere are generally of very low tension, yet they may locally be much denser when solid matters from the coronal region fall into the sun and are vapourised in passing through his atmosphere.

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2. *Colouring Matters of the Diazo-Group.*[1] *By* RAPHAEL MELDOLA, *F.I.C.*, *F.C.S.*

The author commenced by giving a sketch of the history of these compounds, which were first discovered by Griess, and have since been largely investigated owing to their great value as technical products. The diazo-group consists of two nitrogen atoms linked together, $-N=N-$, and, in accordance with the nomenclature proposed by Wallach, diazo-compounds may be termed primary, secondary, or tertiary, according as they contain one, two, or three diazo-groups. Primary compounds have hitherto received the largest share of attention. All the known bodies of importance belonging to this group may be referred to the three types:—

$C_6H_5-N=N-C_6H_5$	Azobenzene.
$C_6H_5-N=N-C_{10}H_7$	Benzene-azonaphthalene.
$C_{10}H_7-N=N-C_{10}H_7$	Azonaphthalene.

The general formula is

$$R-N=N-R.$$

Colouring matters are produced when one or both radicals contain acid or basic substituents.

Secondary compounds are formed on two types, viz.:

$$R<\begin{matrix}N=N-R\\N=N-Ph\end{matrix} \qquad \text{and} \qquad Ph<\begin{matrix}N=N-R\\N=N-R\end{matrix}$$

I. II.

[1] Published *in extenso* in the *Journal of the Chemical Society*, 'Transactions, November 1883, p. 425.

The latter type (II.), in which a phenol residue is indicated by the abbreviation Ph, comprises such bodies as the phenol-bidiazobenzene,

$$\begin{matrix} C_6H_5 . N=N \\ C_6H_5 . N=N \end{matrix} > C_6H_3 . HO,$$

of Griess. These bodies have recently been studied by Wallach, who terms them diazo-compounds.

Secondary bodies of the first type (I.) are generally derived from amidoazo-compounds. A series of secondary diazo-compounds of the general formula

$$R < \begin{matrix} N=N-Ph \\ N=N-Ph \end{matrix}$$

have been prepared by Wallach by the following method: A diamine is first operated upon, so as to acidulate one of its amido-groups, and the free amido-group is then diazotised and combined with a phenol. The acid radical is then eliminated and the liberated NH_2 group diazotised and again combined with a phenol. The series of operations is thus shown:—

$$R < \begin{matrix} NH_2 \\ NH_2 \end{matrix} \qquad R < \begin{matrix} NH . C_2H_3O \\ N=N . Ph \end{matrix} \qquad R < \begin{matrix} NH_2 \\ N=N . Ph \end{matrix} \qquad R < \begin{matrix} N=N . Ph \\ N=N . Ph \end{matrix}$$

The author then proceeded to give a preliminary account of some experiments which he had been engaged upon, with the object of obtaining secondary and tertiary compounds by a new method. The starting-point in this new process is a nitro-derivative of an amidoazo-compound, or of an azo-phenol:—

$$\underset{\text{I.}}{NO_2 . R . N=N-R . NH_2}, \qquad \underset{\text{II.}}{NO_2 . R-N=N-Ph},$$

The nitro-group is reduced without breaking up the diazo-group, and the amido-group diazotised and combined with a phenol, thus giving rise to tertiary or secondary compounds:—

$$\underset{\text{I.}}{Ph . N=N . R . N=N . R . N=N . Ph}, \quad \text{and} \quad \underset{\text{II.}}{Ph . N=N . R . N=N . Ph}.$$

In illustration of the paper the author exhibited a series of dyed fabrics illustrating all the principal types of the best known commercial products, and specimens of the new secondary and tertiary compounds obtained in the course of the present research.

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3. *Suggestions for computing the Speed of Chemical Reaction.* *By* Professor ROBERT B. WARDER.

Among the published determinations of the speed of chemical action, some have already been discussed in connection with the 'action of mass,' thermo-chemistry, electromotive force, and statical determinations of chemical affinity. In many cases, however, a series of experiments is recorded, showing how far a certain reaction progressed in a certain interval of time, with no attempt to reduce the results to a common standard, or to render them available for quantitative study in relation to other researches. A thorough discussion of all reliable data is very desirable—

1. To discover and investigate the causes of certain discrepancies between published observations and the current theories;
2. To afford more definite information of the nature of certain reactions, and the conditions that determine their speed;
3. To afford numerical data for a fuller study of the relations between speed of reaction and other physical constants; and
4. To suggest fruitful lines for further researches in chemical dynamics.

Among the most interesting achievements in modern organic chemistry are Prof. Menschutkin's determinations of the speed and limits of the etherification of the several classes of alcohols and acids; and yet the published numbers, expressing the 'initial speed' (*Anfangsgeschwindigkeit*) or the extent of the reaction reached

in one hour, are by no means proportional to speeds during the first minute, or under like conditions. Prof. L. Meyer has recently published an excellent work entitled 'Dynamik der Atome;' and yet both the theory and the observations of the variations in speed during the progress of a reaction are passed over very lightly indeed. The prevalent theory of the action of mass is expressed by the equation

$$\frac{du}{dt} = kuv \ldots .$$

where the differential coefficient expresses the rate of change in any substance; $u, v, \ldots$ represent the masses of the substances taking part in the change; and k is a constant. Some observations have been made upon the influence of viscosity, temperature, &c., upon the value of k; but these have been so meagre that Prof. Ostwald's skilful determinations usually seem to contradict the theory in its present state.

Accurate determinations of the speed of a reaction require the greatest care, not only for the measurement of time in addition to mass, but also to control the temperature and other conditions within very narrow limits. Many who have not the laboratory facilities or the natural taste for such researches may engage in the mathematical discussion of results already published. Many determinations of etherification, for various alcohols, acids, intervals, and temperatures, have been in print for twenty years; and yet no summary of the deducible value of k has come to my notice. The chemical section of the Ohio Mechanics' Institute has recently undertaken some work in such computations; suggestions and co-operations from chemists and physicists elsewhere are cordially invited. This subject includes numerous mathematical problems that would afford valuable practice for college or university students, especially those who are candidates for honours. Professors of mathematics who will act upon this suggestion may render valuable aid to the cause of chemical research. The following subjects require special attention:—

I. *Fundamental Units.*—The following provisional system is now suggested: for volume, one c.c.; for mass, the chemical equivalent, expressed in m.g.; and for time, one hour. The unit of speed, as derived from these, would be the transformation of unit of each active body per unit of volume and time. Thus in a normal solution of chloracetic acid (containing 94·5 m.g. in each c.c.) if u and v represent the quantities of acid and water respectively, we should have $u = 1$ and $v = 55{\cdot}5$, nearly.

If the reaction

$$CH_2Cl.CO.OH + H_2O = CH_2(OH).CO.OH + HCl$$

could continue for one hour at unit speed, the chloracetic acid would be entirely decomposed in that time, yielding a normal solution of both glycolic and chlorhydric acid; but, according to the equation

$$\frac{du}{dt} = kuv,$$

the speed will vary with u; if then the reaction *begins* with unit speed, kuv equals unity at that moment, or $k = 0{\cdot}018$.[1]

The minute, hour, and day have all been used by chemists as units of time; possibly one second or 1,000 seconds would be a better unit, for convenience in comparing the constants of speed or of chemical affinity with those of heat, electricity, &c.

II. *Probable Errors.*—A determination of speed requires at least two observations of time and two of mass. A series of observations is generally made; and the probable percentage error will vary greatly, according to the data selected or the method of combining them. The theory of least squares should be so applied in each case as to decide (approximately at least) the relative weights to be assigned to the several determinations, and to calculate the probable error of the result.

[1] Dr. E. J. Mills proposes a different unit of chemical action in *Phil. Mag.* [5] I., 1-16 (1876).

III. *Extensions of the Theory.*—Many determinations which show clearly a diminution of speed with diminution of the product of the active bodies do not accord with the hypothesis that these quantities vary in the same ratio. In such cases there may be a variation in the viscosity, or some secondary reaction; a careful study of the discrepancy or perturbation may lead to a satisfactory hypothesis, and suggest special experiments to test the causes suspected.

IV. *Indirect Determinations.*—Whenever there are reciprocal reactions the conditions of apparent equilibrium may indicate the ratio of the speed of each. Some of these ratios may be combined with constants of speed directly determined, to yield new values; for example, if the constants for etherification are determined, it would be easy to calculate those for the decomposition of ether by water in all cases where the limit of the reaction is known.

V. *Tabulation of Results.*—By bringing all the results obtained into systematic order, this interesting class of data can be made available for comparison with other fields of physical science.

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4. *Ortho-Amido-Cinnamic Acid. By* T. M. Morgan, *B.Sc.*

To this acid, which I first obtained in very small quantity, and probably impure, I was led by the analytical results to assign a composition corresponding to amido-phenyl-glyceric acid ('Chemical News,' xxxvi. 269). It was afterwards described by Tiemann and Oppermann ('Ber. deut. chem. Ges.' xiii. 2061), who prepared it by reduction of ortho-nitro-cinnamic acid by baric hydrate and ferrous sulphate. Its purification is attended with much difficulty when the corresponding nitro-acid is reduced with stannous chloride by reason of the large amount of resinous matter simultaneously produced. I have since prepared the amido-acid in much larger quantity, and find that it possesses the property of forming an acid sodium salt of very stable character, easily soluble in hot water and alcohol, sparingly soluble in cold, and very readily crystallising in flat, thin, rhomboidal plates of bright yellow colour. It may be formed by adding to an alcoholic solution of the sodium salt sufficient acetic acid to combine with half the sodium, or by dissolving in alcohol three molecules of ortho-amido-sodic cinnamate and one of the hydrochloride of ortho-amido-cinnamic acid. This salt is well adapted for the purification of the free acid; the latter is best obtained pure by crystallisation from hot benzine, which yields it in form of long brittle yellow prisms.

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5. *On the preparation of Cinnamic Acid. By* T. M. Morgan, *B.Sc.*

This acid, which has acquired an additional interest of late through being the mother substance from which indigo may, in several ways, be prepared, can now be artificially produced in quantity by two methods.

It is obtained by the well-known Perkins' reaction, when sodic acetate, acetic anhydride, and benzaldehyde are boiled with a reversed condenser for eight or ten hours. In this way, when pure materials are used, almost a quantitative yield is obtained; but if the substances used are not pure, as by the employment of commercial sodic acetate, resinous products will be produced in large quantity and very little cinnamic acid.

The second method has been made the subject of a patent. It consists in the oxidation of cinnamyl-methyl-ketone by alkaline hypochlorites. This method is less advantageous than the foregoing, as the ketone is troublesome to prepare, the reaction by which it is produced taking place slowly, only in very dilute aqueous solutions, and not yielding a product corresponding with the materials employed.

But for the production of cinnamic acid in quantity it is better to employ the old method of extracting it from liquid storax, which yields to prolonged boiling with caustic potash about fifteen per cent. There has been some inconvenience in freeing the acid from a resin extracted at the same time by the alkaline solution; but it will be found that treating the latter with common salt renders it incapable of taking up the resin, or precipitates it if dissolved as a resin soap, the solution then yielding on acidification an almost white precipitate, containing in a dry state

about ninety-four per cent. of cinnamic acid. The remaining impurities are almost insoluble in carbon disulphide, whilst the acid readily dissolves, and is left as a crystalline residue slightly discoloured on evaporation of the solvent.

6. *On Manganese Bronze.* *By* P. M. PARSONS.—See Reports, p. 378.

FRIDAY, SEPTEMBER 21.

The following Reports and Papers were read:—

1. *Report of the Committee on Chemical Nomenclature.* See Reports, p. 127.

2. *Report of the Committee appointed for the purpose of investigating by means of Photography the Ultra Violet Spark Spectra emitted by Metallic Elements, and their Combinations under varying conditions.*—See Reports, p. 127.

3. *Explosion of Carbonic Acid Gas.—A Demonstration.* *By* H. B. DIXON, *M.A., F.C.S.*

4. *Chemical Views on the Constitution of Matter.* *By* Professor A. W. WILLIAMSON, *Ph.D., F.R.S.*

5. *On the Atomic Weight of Manganese.* *By* Professor JAMES DEWAR, *M.A., F.R.S., and* ALEXANDER SCOTT, *M.A., D.Sc.*

At the meeting of the Association in 1881 the authors gave an account of some preliminary determinations of the atomic weight of manganese, arrived at by the use of silver permanganate. This salt is very well fitted for such a purpose, as it is easily obtained in a state of great purity by crystallisation, and is not at all hygroscopic. The first and most direct method employed was reduction by heat alone, and finally ignition in a current of pure hydrogen. The reactions taking place are

$$4AgMnO_4 = 2\,(Ag_2O,2MnO_2) + 3O_2$$
$$2(Ag_2O,2MnO_2) + 6H_2 = 2Ag_2 + 4MnO + 6H_2O.$$

This method unfortunately did not give very concordant results, due probably to the retention of hydrogen and imperfect reduction of the oxide of manganese. Table I. gives the results of several experiments made in this way.

TABLE I.

Experiment	Weight of Silver Permanganate		Weight of Residue Ag + MnO		Oxygen Lost	Equivalent
	In Air	In Vacuo	In Air	In Vacuo		
I.	5·8688	5·8696	4·6320	4·63212	1·23748	227·673
II.	5·4981	5·4988	4·3358	4·33591	1·16293	226·965
III.	7·6725	7·6735	6·0538	6·05395	1·61959	227·422
IV.	13·0997	13·10147	10·3179	10·31815	2·78332	225·943
V.	12·5782	12·5799	9·9104	9·91065	2·66925	226·22
			9·9141	9·91435	2·66555	226·53

The method finally adopted was to dissolve the silver permanganate in nitric acid by the aid of a reducing agent, and then to determine, by the method of Stas, the quantity of pure potassium bromide required for complete precipitation of the silver in solution. The reducing agents which gave the best results were potassium nitrite and sodium formate; sulphurous acid was found to leave after reduction always a trace of what was apparently sulphide, and was besides troublesome from the insolubility of the silver sulphate produced. The results of the titrations are given below in Table II.

TABLE II.

No.	$AgMnO_4$	$AgMnO_4$. Corrected for vacuo	KBr	KBr Corrected for vacuo	Equivalent of $AgMnO_4$	Reducing Agent
1	6·528	6·5289	3·4228	3·42385	227·094	Sulphurous acid
2	7·5368	7·5378	3·9541	3·9553	226·958	Nitrite of Potash
3	6·1000	6·1008	3·20067	3·20166	226·937	,, ,,
4	5·7457	5·74647	3·00584	3·00677	227·606	Sulphurous acid
5	6·1651	6·16593	3·23503	3·23602	226·918	Formate of Soda
6	5·1126	5·11329	2·68216	2·6828	226·984	,, ,,
7	5·0737	5·07438	2·6614	2·66204	227·013	Nitrite of Potash
8	13·4466	13·4484	7·05385	7·05602	226·983	,, ,,
9	12·5782	12·5799	6·59861	6·60065	226·972	Hydrogen
10	12·2686	12·27025	6·4361	6·43808	226·976	Nitrite of Potash

The mean atomic weight of manganese which results from the average of the eight determinations in which sulphurous acid was not employed as the reducing agent is 55·038, oxygen being taken as 16 and silver as Stas's value, 107·93.

Thus another element is added to the list of those whose atomic weights have been found on revision to be exceedingly near whole numbers.

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6. *On the Molecular Weights of the Substituted Ammonias. By* Professor JAMES DEWAR, *M.A.*, *F.R.S.*, *and* ALEXANDER SCOTT, *M.A.*, *D.Sc.*

It seemed to the authors that by the use of the haloid salts of the substituted ammonias, small differences from whole numbers in the atomic weights of hydrogen and carbon would be easily revealed. The difficulty of obtaining perfectly pure substances for such work, together with their hygroscopic properties, introduces serious difficulties; and for the purpose of testing the accuracy of the proposed method, the preliminary experiments have been made with triethylamine.

The triethylamine was prepared from tetrethylammonium bromide, by dry distillation, and the base separated as hydrochlorate. The free base was obtained by treatment of the hydrochlorate with caustic potash, dried carefully, and distilled. The portion boiling between 90° and 91° C. was converted into hydrobromate, and its equivalent relation to silver determined, after the method of Stas, with the following results:—

Weight of Salt in vacuo	Weight of Silver in vacuo	Molecular Weight of $N(C_2H_5)_3HBr$
6·6248	3·9219	182·313
8·24088	4·8798	182·270

A portion of the same fraction was treated with nitrous acid, to eliminate primary and secondary monamines, and the titration repeated with the following results:—

Weight of Salt in vacuo	Weight of Silver in vacuo	Molecular Weight of $N(C_2H_5)_3HBr$
5·3165	3·1519	182·052
4·6237	2·74194	182·001

The result of the nitrous acid treatment has been to lower the molecular weight,

due, probably, to the removal of small quantities of bases derived from more complicated radicals than ethyl.

The whole of the sample of triethylamine was now fractionated with great care, and the portion boiling between 90° and 91° C. selected for a repetition of the process; the middle portion from this second distillation, boiling between 90·2° and 90·4° C., was again separated into three fractions by a new distillation, and the molecular weights of the hydrobromates of the respective samples determined. The results are given in the following table:—

Experiment	Weight of Salt in vacuo	Weight of Silver in vacuo	Molecular Weight of $N(C_2H_5)_3HBr$	Remarks
I.	7·06272	4·18778	182·025	First sample boiling 90°–91° C.
II.	6·4418	3·8199	182 011	Second fraction of I. boiling 90·2°–90·4°.
III.	15·46765	9·18495	181·756	First portion of II. refractionated.
IV.	11·95685	7·0902	182·012	Middle and largest fraction of II. refractionated.
V.	13·9522	8·2664	182·166	Highest boiling point portion of II. refractionated.

Another sample was precipitated as acid ferrocyanide, and on conversion into the hydrobromate its equivalent was found to be 181·752.

The results of the analyses clearly prove that the sample of base is not homogeneous, the presence of higher and lower bases being clearly revealed. At the same time the middle and largest portion of the last fractionation has a molecular weight which may provisionally be accepted as that of pure triethylamine. If the molecular weight of the hydrobromate be 182·012, then we have for triethylammonium, 102·061, and subtracting from this the value of ammonium, 18·074 (Stas), similarly found, we get for the hydrocarbon, C_6H_{12}, the value 83·987. Now, Dumas and others have shown that carbon is 12·005, if oxygen = 16; hence the number 83·987 necessitates hydrogen being less than unity, instead of greater, as is usually acknowledged, when O = 16 is the standard accepted.

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7. *The Length of the Prismatic Spectrum as a Test of Chemical Purity.* *By* Dr. J. H. Gladstone, *F.R.S.*

The specific refraction of any chemical substance is a very constant property, and may be used to determine the purity of any specimen. Landolt in fact showed how a mixture of two known substances, such as ethylic and methylic alcohol, in unknown proportions might be analysed by means of it. The object of the present communication is to point out that specific dispersion, i.e. the length of the spectrum divided by the density, is in many cases a still more delicate test of purity. The absolute determination of a refractive index is subject to many sources of error; but the almost simultaneous measurement of the two extreme lines of a prismatic spectrum can be effected with great comparative accuracy, and in the author's observations the error of dispersion probably rarely exceeds ± 0·0002. It was found that different specimens of benzene, bisulphide of carbon, hydrocarbons from essential oils, cymene, &c., often differed from one another by five or ten times the above amount, while the differences of refraction scarcely exceeded those of probable experimental error. That impurities otherwise unsuspected may reveal themselves by their effect on the length of the spectrum is apparent from the fact that, whereas the specific refraction of organic bodies for the line A varies only from ·410 to about ·570, the specific dispersion from A to H varies from ·0162 to at least ·0632. It is the aromatic compounds, or still more such bodies as naphthalene, where the number of carbon atoms is in excess of that of the other elements, that

produce the greatest effect on the length of the spectrum. It was shown that a mixture of 1 per cent. of benzene in alcohol, or of cymene in turpentine, or *vice versâ*, could be easily detected by this method.

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8. *The application of Bisulphide of Carbon to the Scouring of Wool. By* Professor WILLIAM RAMSAY, *Ph.D.*

After a short review of the old processes of cleansing and scouring wool, the author described the process invented by Mr. Mullings, of George Street, London, known as the 'turbine process.' It consists in dissolving out smut and fatty matters from wool by means of carbon disulphide. To effect this the wool is placed in a special form of hydro-extractor, covered with a dome-shaped cover, evaporation of the solvent being guarded against by water-joints. Bisulphide of carbon is then admitted, so as thoroughly to soak the wool, and the machine being caused to rotate the solvent is expelled; the last traces are driven out by admitting *cold* water. The features of the process, which distinguish it from all other similar ones, and which secure its success, are the avoidance of a high temperature and the use of cold water in expelling the solvent. The bisulphide runs into settling tanks, where it is separated from the water; and thence it is removed to retorts and distilled, leaving a residue of suint. Attention was drawn to the fact that the French bisulphide, made from coke, gave much better results than the English bisulphide, made from charcoal.

The wool cleansed by this method has a better appearance, gives a finer yarn, and may be woven into a fabric preferable to that given by the old process.

It is calculated that the annual saving in England which would be caused by the introduction of the turbine process would amount to close on a million and a half sterling.

Details of the process were given in the paper.

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9. *On the Conversion of Oleic Acid into Palmitic Acid, and Fusions with Caustic Alkalies at High Temperatures. By* WM. LANT CARPENTER, *B.A., B.Sc., F.C.S.*

At the March meeting of the London Section of the Society of Chemical Industry the author drew attention to the mode of procedure whereby M. Radisson, of Marseilles, was able to carry out on an industrial scale Warentrapp's reaction (announced in 1841) of

$$C_{18}H_{34}O_2 + 2KHO = C_{16}H_{31}KO_2 + C_2H_3KO_2 + H_2.$$

At the last Paris Industrial Exhibition M. Fournier, of Marseilles, the largest stearic acid maker in France, exhibited palmitic acid candles which had been made from oleic acid by this process.

Considerable interest was excited at the meeting above referred to as to the exact way in which these potash fusions on so large a scale were carried out, and the author was asked for many details which he was then unable to give. Since then he has spent a week at Marseilles studying the process, and now submits some new details to the Section.

The fusion is effected in a vessel called a 'cartouche.' It is cylindrical, with a dished bottom of cast iron, 3·20 metres in diameter; the sides and top are of wrought iron, 1·30 metre in height; a mechanical agitator works in the interior, and an exit-pipe leads through a coke tower-condenser to a gasholder, to collect the hydrogen. The fire-bars are about 1·75 metre from the bottom of the cartouche, and the fire is only a few centimetres thick. At the commencement 1,500 kilogrammes of oleic acid and 2,500 kilogrammes of caustic potash ley at 43° B. sp. gr., are pumped into the cartouche, and the temperature is slowly raised to 300° C. Evolution of hydrogen commences at 290°. Between that and 320° the reaction takes place, and at 320° the process is arrested by the injection of steam by a Giffard's injector. All access of air must be avoided during the operation,

which is best done by maintaining an atmosphere of steam in the cartouche. The time necessary for a complete operation is from thirty-six to forty hours. In addition to acetic acid and hydrogen, caprylic alcohol, sebacic acid, caproic acid, and a new acid for which the name hippomic is proposed, are among the products of the reaction, and in the case of some fats hircic acid also. Hydrocarbons of the paraffin series are usually formed also.

Owing to the want of fluidity of sodium oleate, and its bad conducting power for heat, the process has to be somewhat modified for a caustic soda fusion. Of the various substances tried, to give the mass fluidity, the use of paraffin has been attended with the greatest success, and the author saw a successful conversion effected in this way on a large scale for a laboratory.

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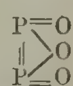
10. *On the Action of Sunlight on* P_2O_3.[1] *By the* Rev. A. Irving, *B.Sc.*

Following Wislicenus, the author finds that carefully prepared P_2O_3, when exposed in hermetically sealed tubes to the action of direct sunlight, is entirely replaced by amorphous phosphorus and P_2O_5 (the latter proved by the amm. molybdate test). The author has also found that if one of these tubes in which the transformation has been effected is kept for a long time, a plentiful growth of crystalline P takes place upon the walls of the tube, apparently by slow sublimation of the red P.

The author suggests, as an explanation of the reduction of some of the P_2O_3 to P, the loosening of the bond which holds P to P in the molecule, as would be shown in the graphic formula



In a layer of a considerable fraction of a millimetre in depth the molecules directly in contact with the glass wall of the tube would be first acted upon, and most strongly by sunlight; the effect of this he conceives to be the loosening of the double bond which holds P to P, and an alteration in the *relative* strength of the affinities of P to P and of P to O. It is not difficult to see how, under such altered conditions induced by the action of a purely physical agent (heat as well as light will produce the result), the molecules of P_2O_3 which are not so strongly acted upon may, by their greed for oxygen (as shown by their spontaneous inflammability in moist air), act as a reducing agent upon the contiguous molecules which are more directly exposed to the action of light. This would perhaps explain the reaction which Wislicenus suggests, as follows:

$$5P_2O_3 = P_4 + 3P_2O_5.$$

The explanation which has been suggested above seems also to help us to understand why the phosphide P_2H_4 is spontaneously inflammable in air, whereas the phosphide PH_3 is not so.

The author is inclined to attach some importance to the notion here suggested as illustrating the disturbance of chemical equilibrium and consequent partial dissociation, as a preliminary to chemical reactions.

SATURDAY, SEPTEMBER 22.

The Section did not meet.

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[1] Printed *in extenso* in the *Chemical News*, vol. xlviii. Oct. 12, 1883.

MONDAY, SEPTEMBER 24.

The following Papers were read :—

1. *On Liquid Marsh Gas. By* Professor DEWAR, *F.R.S.*

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2. *On Critical Points and Pressures and their relation to Atomic Volumes. By* Professor DEWAR, *F.R.S.*

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3. *On the relation between Chemical Constitution and Crystalline Form. By* G. JOHNSTONE STONEY, *F.R.S.*

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4. *Electrolysis of dilute Sulphuric Acid in Secondary Batteries. By* Dr. J. H. GLADSTONE, *F.R.S., and* ALFRED TRIBE.

The authors in their recent papers had given the results of the chemical changes which take place in charging and in discharging secondary batteries of the Planté or Faure type. In expressing these changes by means of formulæ they had assumed that the compound decomposed in the cell was H_2SO_4. The present communication was to consider more fully the question as to what the compound electrolysed actually is. Is it water, as used to be supposed? Is it the actual H_2SO_4? Or is it some chemical combination of the two, such as hexabasic sulphuric acid, which Frankland has lately assumed to be the electrolyte on the authority of Bourgoin's experiments? The authors had tested the value of these experiments by means of a divided cell, in one limb of which was a solution of sulphate of copper, and in the other dilute sulphuric acid. They found that, independently of the actual molecular change, which in accordance with Grotthus' hypothesis must ensue during electrolysis, there was also an actual passage of sulphuric acid into the limb containing sulphate of copper. The conclusion from this and other experiments was that we have no data to determine whether it is sulphuric acid or some hydrate that is electrolysed; but analogy would lead to the conclusion that it is sulphuric acid itself. Hence they retain the former simple method of representing the phenomena.

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5. *On the Mobility of Gold and Silver in Molten Lead. By* Professor W. CHANDLER ROBERTS, *F.R.S.*

The author showed that metals interpenetrate when molten at very varying rates. Antimony and copper, for instance, alloy with comparative slowness, but on the other hand the mobility of silver and gold in lead and in bismuth is so rapid as to more nearly resemble the rate of diffusion of gases than that of a crystalline salt in a liquid. The methods of manipulation were given at length, and consist generally in observing the rate of passage of gold, starting with an alloy containing 30 per cent. of the precious metal, through a curved or straight column of molten lead or bismuth. Exact numerical determinations have yet to be made.

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6. *On Algin, a new substance obtained from Seaweed.*[1] *By* EDWARD C. C. STANFORD, *F.C.S.*

The author points out that a large fringe of marine vegetation surrounds the shores of Great Britain and Ireland, and that this constitutes an immense amount of raw material which is almost unutilised. The subject is discussed under three applications; for food, for manure, and for the manufacture of kelp. There ought to be a large application for food, as the plants are highly nitrogenous, resembling

[1] Published *in extenso* in the *Journal of the Glasgow Philosophical Society*, 1883; also in *Chemical News*, 1883, and *Pharmaceutical Journal*, 1883.

the fungi, with the important difference that they contain no poisonous species. For manure the algæ, containing 80 per cent. of moisture, are of little value as against artificial manures. The manufacture of kelp, or seaweed ash, is gradually dying out; it is only now one of the sources of iodine, and it never really utilised the seaweed. The commoner species, named in the order in which they grow, are the *Fucus vesiculosus*, *F. nodosus*, *F. serratus*, *Laminaria stenophylla*, and *L. digitata*. These all contain the new substance. It can often be seen in the long fronds of the Laminaria as a sac of glairy fluid, which, when evaporated, yields a kind of vegetable albumen called algin. This substance has some characteristic properties; it is instantly coagulated by mineral acids, even a 2 per cent. solution becoming semi-solid. Acetic acid does not affect it. Lime-water and the salts of the alkaline earths, with the exception of magnesium, also coagulate it. Boracic acid does not affect it. It is precipitated by alcohol. Metallic salts generally precipitate it, but mercury bichloride has no effect. It differs from albumen in not coagulating on heating.

It contains nitrogen, but no sulphur. It is insoluble in water, and requires about 20 per cent. of sodium carbonate for its solution.

The method adopted for treating the seaweed is as follows. The seaweeds are first macerated in cold water, which removes about a third of the weight. The residue is bleached by a weak solution of chlorinated lime, acidulated with hydrochloric acid. It is then acted on in the cold with about a tenth of its weight of sodium carbonate, heated, filtered, and evaporated. The residue in the filter is cellulose, pretty pure, and ready at once for making paper.

The salts from the water solution vary according to the plant; an average sample from Laminaria is appended:—

Calcium sulphate	1·69
Potassium sulphate	11·29
Potassium chloride	19·90
Sodium chloride	60·96
Magnesium chloride . . .	4·35
Sodium carbonate	·53
Sodium iodide	1·26
	99·98

The whole of the salts are thus obtained, and in addition some saccharine matter resembling mannite.

Applications.—The algin, which can be obtained in large quantity, has been applied as a stiffener of fabrics, replacing starch, than which it is tougher and more transparent. It forms an excellent mordant in dyeing, being easily rendered insoluble. It is an efficient 'boiler fluid' for precipitating the lime salts and preventing incrustation. In the insoluble form it much resembles horn and bone, and can be employed to replace those substances. It possesses great agglutinating power, and will convert sand, plumbago, chalk, and such difficult substances, into solid hard blocks. Under the form of 'carbon cement' it has been largely used for covering steam boilers as a non-conductor of heat, the cement consisting of charcoal containing about 3 per cent. of algin; the charcoal employed is from seaweed, so that the whole coating is made from that material.

It is a good non-conductor of electricity, and an efficient agent for emulsifying oils and for fining wines and spirits. By the process indicated the whole plant is utilised for the first time. The importance of the new industry to the Highlands and the West of Ireland can scarcely be overrated.

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7. *Methods for Coking Coal and recovering the Bye-products.*[1]
By WATSON SMITH, *F.C.S.*, *F.I.C.*

There are various forms of plant for coking coal, for the production of coke for metallurgical purposes, which may be classed as follows:—

[1] Printed *in extenso*, *Iron*, Oct. 5, 1883, p. 310; *Journal of Gas Lighting*, Oct. 30, 1883, p. 742; *Chem. News*, Oct. 19, 1883, p. 185.

1. Those accompanied with no utilisation or recovery of the bye-products.

2. Those utilising the bye-products merely as fuel, burning them, but recovering none.

3. Those recovering bye-products, and utilising as fuel the gaseous portion thereof.

Representative forms of the 1st kind. (i.) The Meiler or Mound. (ii.) The Beehive oven.

Representative forms of the 2nd kind. The Appolt and Coppée ovens.

Representative forms of the 3rd kind. (A.) Admitting air, and so involving partial combustion. The Jameson oven.

(B.) Closed ovens, and thus involving destructive distillation, Knab's, Pauwell's and Dubochet's, Pernolet's and Simon-Carvés's ovens.

In Jameson's oven is a simple modification of the Beehive form. Jameson substitutes for the solid floor of the latter oven, one of perforated quarls, but quite recently finding difficulty in the stopping-up of the perforations, he uses tiles, placed on sleeper-walls, and somewhat apart, so as to allow spaces between them. From this floor and underneath it a pipe passes to the hydraulic main, and in this way all the ovens are connected with the hydraulic, and thus with the usual scrubbing and exhausting apparatus usual in gasworks.

The coke obtained by Jameson's process is good, in fact like that from the Beehive oven. As regards ammonia, Jameson states that he can obtain ammoniacal liquor equal to a production of from 5 to 15 lbs. of sulphate of ammonia per ton of coke (equalling about 3 to 9 lbs. per ton of coal). Truly there is a somewhat uncertain sound given by these figures, betokening some want of definiteness, and that they cannot be derived from an average involving trials on a really large scale.

The returns Jameson gives of tar yielded per ton of coal, viz. 6 to 15 galls. per ton of coke (equalling about 3½ to 9 galls. per ton of coal) are also somewhat bewildering, and do not appear to have been derived as averages of extensive trials so much as from the results of scattered experiments. However, this tar or tar-oil the author has carefully examined, and finds it to possess all the characteristics of tars produced at low temperatures. It has a specific gravity of 0·960. No benzol is present in this tar, but the statements which have been frequently made to the effect that no aromatic substances, only paraffins, are present, is not true. Small quantities of toluol and of xylol are certainly present in admixture with bodies of the marsh-gas series. The chief bulk of the Jameson tar, however, consists of oils boiling between 250° and 350°, and these oils suitably purified and refined the author has found to be of little value for burning-lamps, and but of secondary value as lubricants. They are quite devoid of blueness or fluorescence. A considerable proportion of oil distils over above 350°, viz. from something like 400° to the point at which pitch remains in the retort, and from these oils paraffin scale does separate, though in unsatisfactory quantity. The paraffin wax obtained has a high melting point, viz. about 58° C.: the paraffin wax of the Scottish shale distillers melting at about 52° C.

The crude phenols extracted in the usual way from the oils boiling between 200° and 300° contain a series of phenols of increasing boiling points of a most peculiar kind, certain of them resembling the constituents of the creosote of wood-tar. Moreover, others of these phenols produce in combination with alkalis blue or violet and red-coloured compounds, decomposed by acids, with destruction of the colours. These colours are of no stability or value. Not a trace of either naphthalene or of anthracene is present in Jameson's tar. Amongst the closed ovens, the Simon-Carvés is the best form, for it yielded excellent metallurgical coke, only lacking the silvery glance of the Beehive product, but possessing even more density and solidity.

The ammoniacal liquor obtained amounts to 27·7 gallons at from 6° to 7° Twaddell, and the tar, which the author has found to be almost identical in composition with the best London coal tars, and having a specific gravity of 1·20, to 6·12 gallons per ton of coal respectively. These are the average results from the coking of 7,000 tons of coal in the Simon-Carvés's ovens at work at Messrs. Pease's West

Collieries, in Crook by Darlington, and the Messrs. Pease are so satisfied with the work done, that to the 25 ovens with which the above results were obtained as regards bye-products, 25 more ovens are being added. The yield of coke in the above experiment was excellent, viz. 77 per cent. of the coal used. It has been stated that the coke drawn from the Carvés's ovens, after watering to effect rapid cooling, becomes too wet. This could easily be obviated by drawing immediately into underground vaults, adding a little water to choke out combustion, and fastening on the lids of the vaults.

In the Carvés's ovens large charges of $4\frac{1}{2}$ tons are used, and these can be coked in 48 hours. The gas is drawn from the ovens by an exhauster so slowly that a slight pressure is always caused to exist in the ovens so as to prevent air being sucked in. This gas is then condensed, and scrubbed to separate tar and ammonia water, and finally returns to the ovens, under the bottoms and around the sides of which it circulates through bottom and side flues. On entering the bottom flue by a jet contained in an annular tube, air is also drawn in and mixed with the gas to effect the perfect combustion of the latter. But this air has already received a preliminary heating to as high as 600° C. by passing in circulating flues from the outside air, these flues enwrapping and co-circulating so to speak with hot and waste gas flues which thus serve to heat up the air in the air-flues. Thus the waste gases pass in their flues in the opposite direction taken by the air drawn through its flues towards the annular pipe, by which it is mixed with the fuel-gas as it enters the bottom flue of the oven furnace.

This improvement of a subsequent heating of the air has raised the temperature attainable in the ovens from 2,200° to 3,000° Centigrade.

Finally, the Carvés's tar contains large quantities of naphthalene and anthracene, as well as benzol, toluol, xylol, and carbolic acids, and so far as I know it is the only coke-oven tar furnished which is really and completely identical with the coal tars of the gas-retorts.

TUESDAY, SEPTEMBER 25.

The following Report and Papers were read:—

1. *Report of the Committee for Investigating Isomeric Naphthalene Derivatives.*—See Reports, p. 132.

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2. *On the alleged Direct Union of Nitrogen and Hydrogen.*[1] *By* H. Brereton Baker.

Doubt having been expressed as to the statement by Mr. Stillingfleet Johnston[2] that the elements nitrogen and hydrogen may be caused to unite directly, the following experiments were undertaken to test the accuracy of his results.

Pure nitrogen was obtained by exposing moist phosphorus in air contained in a bell-jar, the absorption of oxygen being rendered complete by passing the gases through three wash-bottles of potassium pyrogallate. Pure hydrogen was prepared by dissolving zinc in sulphuric acid, and passing the gas through two cylinders containing marbles soaked in potassium permanganate solution. The two gases were dried by passing through a wash-bottle of strong sulphuric acid. They were tested for ammonia by passing them through a tube containing Nessler's solution. They were then passed over heated spongy platinum, and into a second tube of Nessler's solution.

Three experiments were made, two lasting for an hour and a half each, while the third was carried on for two hours. In the last experiment the platinum

[1] *Chem. News,* Oct. 19, 1883. [2] *Jour. Chem. Soc.* 1881.

sponge was heated to bright redness by the gas blowpipe for half an hour, a dull red heat being employed in the other cases. In none of these experiments was the slightest trace of ammonia formed.

Another series of experiments was performed with different apparatus. A glass U tube was made, with one arm much longer than the other. The end of the shorter arm was sealed, and some spongy platinum placed in the sealed end. The open end of the tube was made to dip under a solution of potassium pyrogallate. By means of a flexible tube, air was removed from the longer limb, until only 20 cc. of air remained in the tube. It was allowed to stand over the alkaline pyrogallate till all the oxygen was absorbed. After replacing the pyrogallate in the longer limb by pure water, hydrogen was added by holding a pellet of sodium under the open end of the tube. The spongy platinum was heated, sometimes by a Bunsen lamp and sometimes by the gas-blowpipe. When the tube was cool, Nessler's solution was passed up the longer limb by a bent pipette, and owing to the peculiar shape of the tube, it could be shaken about in the gas without wetting the spongy platinum. In no case was ammonia formed.

Mr. Johnston found that ammonia was produced when hydrogen and the gas obtained by heating ammonium nitrite were passed over heated platinum sponge. It is known that oxides of nitrogen are produced by the decomposition of ammonium nitrite, together with nitrogen gas. To free the nitrogen from these oxides, Mr. Johnston used an elaborate absorbing apparatus. After leaving the absorbers of nitric oxide, it was mixed with hydrogen and passed through three wash-bottles of ferrous sulphate solution, and then over the heated platinum sponge. The amount of ammonia was less by one half than that produced in the former experiment. Before mixing with the nitrogen, the hydrogen was passed through a wash-bottle of silver nitrate. This introduces a new source of error. Hydrogen decomposes a solution of nitrate of silver with evolution of oxides of nitrogen. The author made some experiments to see if the three wash-bottles of ferrous sulphate, used by Mr. Johnston, were adequate for the removal of these oxides. He found that they were not.

It may be concluded, therefore, that all the ammonia produced in Mr. Johnston's experiments was the product of the reaction between hydrogen and an oxide of nitrogen, under the influence of spongy platinum. Hydrogen, therefore, does not unite directly with nitrogen when the mixed gases are passed over heated spongy platinum. Consequently, as far as our present evidence goes, we must regard Mr. Johnston's statement that nitrogen exists in two allotropic modifications as having no foundation.

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3. *On the Decomposing Action that Chloride of Aluminium exerts on Hydrocarbons. By* Professors C. Friedel *and* J. M. Crafts.

The authors began by calling to mind their previous researches showing that the synthesis of hydrocarbons, and of ketones, may be effected by the action of aluminic chloride on a mixture of an aromatic hydrocarbon with the chloride of a hydrocarbon radical, or of an acid radical, and that the anhydrides of acids, and even oxygen and sulphur, enter into similar reactions with aromatic hydrocarbons.

In the course of these investigations they observed that aluminic chloride exerts a decomposing action on complex hydrocarbons, and it is this action that they have now examined more in detail, in the hope that it might throw some light on the mechanism of the synthetic action of aluminic chloride.

Naphthalin was distilled with 25 per cent. aluminic chloride, when the distillate was found to consist of benzol and hydrides of naphthalin, and a carbonaceous residue remained. The hydrides are partly soluble in sulphuric acid, the insoluble portion contains a large proportion of $C_{10}H_{18}$, or $C_{10}H_{20}$, and this hydrocarbon boils at about 183°.

The portion boiling between 204° and 206° appears on analysis to be $C_{10}H_{12}$.

If the naphthalin is digested with the chloride of aluminium at a lower temperature, obtained either by mixing it with benzol or heating it in an oil-bath to 160°, the products are altogether different.

In this case the products have a much higher boiling point, consisting chiefly of isodinaphthyl which may be separated from the oils that accompany it by crystallisation from benzol or petroleum ether.

This isodinapththyl melts at 187°, and boils at 485° (by air thermometer), and yields a picrate greatly resembling that of naphthalin. The liquid portion, distilled again with aluminic chloride, gave benzol, naphthalin, and hydrides of naphthalin, while the isodinaphthyl treated in the same way was almost completely carbonised.

We may therefore conclude that naphthalin gives isodinaphthyl and hydrides boiling at a high temperature, and that these latter afterwards produce benzol and naphthalin hydrides.

Benzol is not affected at its boiling point, but if heated with aluminic chloride in sealed tubes to 235° C. it becomes very brown, and on opening the tube a good deal of gas escapes; this gas burns with a pale flame, and the contents of the tube distilled with water give hydrocarbons boiling from 80° to 160°. When the temperature does not rise above 200° no gas is found in the tubes, even when these are heated for eighteen hours. On fractionation two-thirds of benzol is recovered, the rest consists of toluol (whence benzyl chloride was prepared in order to establish its identity), ethylbenzol, and a portion boiling above 200° which on crystallisation from alcohol melts at 69° and boils at 250–255°, and has the properties of diphenyl.

Diphenylmethane distilled with aluminic chloride gives a mixture boiling at 80°–120°, containing benzol and toluol.

Triphenylmethane distilled with more than half its weight of chloride of aluminium gave only benzol. Triphenylmethane, mixed with seven times its weight of benzol, and heated with chloride of aluminium for two days in an oil-bath to a temperature just below the boiling point of the mixture, gave nearly half its weight of diphenylmethane.

Hexamethylbenzol heated with one-third of its weight of chloride of aluminium for three-quarters of an hour gave off plenty of a non-illuminating gas, and left a product boiling at 200–220°, from which crystals of durol were deposited (melting at 97°), the mother liquor being the isomeric tetramethylbenzol.

Durol gives off gas, a portion boiling at 150°–160°, the chief portion at 190°–200° containing trimethylbenzol mixed with some xylol.

In the case of the poly-substituted methyl benzols one or more methyl groups is displaced by hydrogen; in all cases very little hydrochloric acid is given off.

In order that the same hypothesis may explain both the destructive and the synthetic action of aluminic chloride, the authors suggest that whereas they have formerly assumed that the equation $C_6H_6 + Al_2Cl_6 = C_6H_5Al_2Cl_5 + HCl$ represents the first stage in the synthetical reactions, so this same equation is also the first stage of the present decompositions. They assume that the compound of $C_6H_5Al_2Cl_5$ is broken up by heat into diphenyl and subchloride of aluminium, and that the latter is decomposed by the free hydrochloric acid into aluminic chloride and hydrogen, and that it is the hydrogen thus set free that exerts the reducing action observed.

Thus benzol is reduced to the groups methyl and ethyl, which give rise to methyl and ethylbenzol.

Naphthalin forms dinaphthyl and its hydrides, the latter giving naphthalin hydrides.

In the case of di- and tri-phenylmethane and the methylated benzols, the group Al_2Cl_5 seems to displace a phenyl or methyl group, which, under the reducing action of the mixture, appears as benzol or methane respectively.

It is also to be observed that a quantity of carbonaceous matter, evidently poor in hydrogen, is always formed.

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4. *On the Nitrates in Soil. By* R. Warington, *F.C.S.*

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5. *On a Simplified Thermostat. By* M. WHITLEY WILLIAMS, *F.C.S.*

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6. *Some Experiments on Asbestos. By* M. WHITLEY WILLIAMS, *F.C.S.*

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7. *On the Constitution of the Natural Fats. By* J. ALFRED WANKLYN *and* WILLIAM FOX.

The received view of the constitution of the natural fats is that they are ethers of glycerin. Furthermore, it is generally maintained that the natural fats are tri-glycerides—that is to say, that they are fully saturated ethers of glycerin. The recognised exceptions are spermaceti (which is palmitate of cetyl) and cholesterine, the constitution of which is regarded as being uncertain. Our investigations have led us to the conclusion that among the natural fats must be enumerated a new class of compounds, viz. the ethers of iso-glycerins, and also that di-glycerides, or two-thirds saturated ethers of glycerin, are to be met with among the natural fats.

In collecting the actual experimental data relating to the natural fats, the authors have noted that, whilst the theoretical, or very nearly theoretical, yield of the fatty acids has frequently been obtained from a fat, the theoretical yield of the glycerin is missing. When a ton of tallow is subjected to the action of steam, they are informed that 10 cwt. of oleic acid, and 9 cwt. of stearic acid, and 1 cwt. of glycerin are the products. The theory requires that 2 cwt. of glycerin should be given.

When Dupré subjected a weighed quantity of butter to the action of water at elevated temperatures, the sum of the fatty acids and the glycerin fell considerably short of the total required by the equation.

The marked failure to get the theoretical yield of glycerin is a fact which demands an explanation. That explanation the authors are prepared to supply as follows:—'They hold that accompanying the glycerides there are iso-glycerides. From its structure an iso-glyceride can yield neither glycerin nor iso-glycerin when it is saponified, but must yield water and the corresponding fatty acid.

The structural formula of common glycerin is—

$$\begin{matrix} C_1H_2OH \\ C_1HOH \\ CH_2OH \end{matrix}$$

and glycerin can exist in an isolated condition.

The structural formula of iso-glycerin is—

$$\begin{matrix} C_1(OH)_3 \\ C_1H_2 \\ CH_3 \end{matrix}$$

and iso-glycerin exists only in its ethers, but cannot exist in an isolated condition. When an ether of iso-glycerin is saponified, the iso-glycerin is resolved into water and the corresponding fatty acid, thus—

$$\begin{matrix} C_1(OH)_3 \\ C_1H_2 \\ CH_3 \end{matrix} = \begin{matrix} C_1OOH \\ C_1H_2 \\ CH_3 \end{matrix} + H_2O$$

The iso-glycerins are a class of homologous bodies. The following are the formulæ and names which the authors propose:—

Methan-iso-glycerin, $CH(OH)_3$.—The triethylate of this lowest term of the series is one of the forgotten bodies of organic chemistry. Many years ago Kay discovered it. The ether got when chloroform acts upon ethylate of sodium is the body in question, which possesses the characteristic property of yielding no corresponding tri-atomic alcohol but yields the corresponding acid, which in this instance is formic acid.

Ethan-iso-glycerin, $CH_3C(OH)_3$.—Its ethers give acetic acid when saponified.

Propan-iso-glycerin, $CH_3CH_2C(OH)_3$.—Its ethers give propionic acid when saponified.

Tetran-iso-glycerin, $CH_3CH_2CH_2C(OH)_3$.—Its ethers give butyric acid when saponified. An ether of this iso-glycerin forms one of the principal constituents of butter. A mixture of butter and alcohol may be heated so that the alcohol distils off, and no trace of butyric ether will be observed in the distillate. But if a stick of potash be added, then butyric ether will immediately begin to be formed, and may be obtained in abundance.

The butyric ether formed under these conditions is the representative of the tetran-iso-glycerin, which, in the form of di-palmitate or di-oleate, existed in the butter.

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8. *On the Employment of Limed Coal in Gas-making.* *By* J. A. Wanklyn.

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9. *On the Development of Crystals from Transparent Glass by the Action of Solvents upon it.* *By* William Thomson, *F.R.S.E.*

Transparent glass has usually been regarded as an amorphous substance, but, from experiments which the author recently made, he has been led to believe either that it is crystalline, or that its structure is peculiarly interesting.

Professor Tyndall, in speaking of the beautiful crystalline structure of transparent ice, shown by means of a beam of the electric light which, passing through it melts some portions of the ice so as to develop six-petalled flower-like crystals, the images of which are thrown upon the screen, says that the molecules of the ice present a marked contrast to those of glass, which are devoid of symmetry or crystalline structure.

It occurred to the author that if glass could be melted in a manner similar to ice, one could imagine it possible that it might be demonstrated that the molecules of which glass is composed might also be shown to be built up in a manner no less symmetrical or beautiful than those of ice.

With a view of undoing the structure of glass to determine whether it had anything of a symmetrical or crystalline nature, he treated some ordinary glass microscope slides with hydrofluoric acid in different ways, but found that it produced a nodular appearance in the crevices formed by the etching process. On microscopical examination, he observed that these nodules were arranged to each other as if they were crystals with their edges dissolved off, and the general arrangement of these nodules to each other further indicated a crystalline or symmetrical structure. Believing that hydrofluoric acid acted too vigorously, he endeavoured to find another agent to act upon glass with less energy.

Neutral sodium fluoride had very little action upon glass, but acid sodium fluoride acted upon it with considerable energy. The fluoride when removed from the glass by washing and scrubbing with a hard nailbrush in a stream of water to remove any adherent matter, drying, and then examining by the microscope, showed that the sides of the crevice formed by the etching were composed of myriads of well-defined hexagonal pyramids, most of them appearing as if built up in layers, showing a series of steps.

Neutral ammonium fluoride was found to act on glass, although not rapidly. When a drop of a solution of ammonium fluoride containing excess of ammonia was put on glass, heated to evaporate the water, and the heat continued till the ammonium salt volatilised, it was found on washing the glass in a stream of water, scrubbing with a hard brush, drying, and examining by a microscope or good pocket lens, that the surface touched by the liquid had been removed, and that it had been resolved into beautiful fern-like crystals such as may be observed by the freezing of moisture on the surface of window-panes in winter.

Lastly, when a drop of the ammonium fluoride solution was left on the glass in the cold over night, it removed the surface of the glass here and there all over, producing well-defined five- and six-sided figures, the surface of the glass being removed within the figures.

The results of these experiments lead the author to believe that transparent glass,

which has been usually regarded as amorphous, is either built up of crystalline forms, or, as has been suggested to him by Professor T. G. Bonney, the amorphous silica in the glass rearranges its molecules and becomes crystalline.

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10. *On certain Molecular Movements in the vicinity of thin Iron Plates.* *By* WILLIAM THOMSON, *F.R.S.E.*

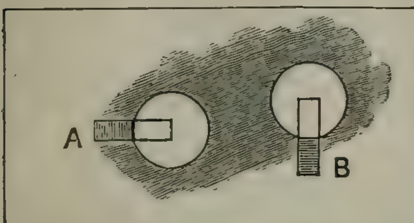
The experiments described in this paper were a continuation of those made by the author some time ago, the results of a number of which were brought by him before this section two years ago. At that time he was under the impression that certain phenomena which were produced by leaving iron in contact with wet prussian-blue dyed cloth resting on wet blotting-paper, appeared to be due in some way or other to magnetic action, which had directly or indirectly caused the well-defined lines of insoluble prussian-blue which appeared to have flowed from the iron into the blotting-paper underneath the cloth. Since then he has made experiments with iron strongly magnetic, and simultaneously with similar pieces of iron which were only magnetic from the action of the earth's magnetism. In each case the lines of colour were produced, but they developed to a greater distance, and much more regularly, from the piece of iron which was very slightly magnetic, than from the one which was strongly magnetised.

In one series of experiments slips of thin iron, $\frac{11}{16} \times \frac{3}{16} \times \cdot 0075$ inch, cut from ferro-type photograph plate cleaned and polished, were placed on slips of glass and covered by thin layers of glycerine jelly, coloured by prussian-blue (which was developed by the action of potassium ferricyanide on ferrous sulphate), containing also a slight excess of ferricyanide, and made faintly acid with hydrochloric acid. One of these was laid aside, and the other supported on the poles of a horse-shoe magnet placed with its poles upright, the glass being kept in position by the action of the magnet on the slip of soft iron on the other side of the glass: the slip of soft iron was thus rendered magnetic. In each case a deep-blue colour extended out from the iron all around, forming an oval, but the colour extended more rapidly from the iron which was not rendered magnetic, than from the other which was magnetised. The colour then collected round the margin of the oval from the former, and became most intense at the two ends. Four well-defined thin straight lines of the prussian-blue colour then developed from the ends of the oval, going towards each other at an angle of about 45° from the line of the metallic slip till they came to the margin of the jelly on the glass; and some weeks later other well-defined but curved lines developed from the ends of the oval, which gradually exfoliated until five had formed at each end of the oval going in beautifully formed curves to the edge of the glycerine jelly. The slip placed over the magnet formed a deep-blue oval round the iron slip; about one-half the area of the oval ultimately formed round the non-magnetised slip, and no lines of colour developed from it.

Presumably the deeper blue developed around the iron in these two experiments was due to the action of the acid upon it, and the combination of the ferricyanide with the iron thus brought into solution. Another similar experiment was made by using the same proportion of ferricyanide and acid, but without the addition of ferrous sulphate to colour the jelly blue. In this case prussian blue formed a thick coating on the top of the iron slip, but it did not extend outwards from the margin of the slip. In a third experiment a drop of jelly, deeply coloured with prussian blue, was placed on the surface of transparent glycerine jelly, but after nearly two years the colour had not extended in the faintest degree into the colourless medium. In a fourth experiment a slip of blotting-paper, the size of the iron slips used in the first-mentioned experiment, saturated with a solution of ferrous sulphate and dried, was placed in part of the coloured jelly mixture first mentioned. A blue colour, deeper than that of the surrounding jelly, gradually extended outwards, forming after a few weeks a small oval round the paper, which did not increase in size or undergo any further alteration after two years.

From these last-mentioned results one is led to believe that molecules of colouring matter distributed throughout the solid medium of the jelly aid in the spreading or diffusion throughout its mass of colouring matter similar to itself, and that the curved and straight lines of blue colouring matter are directly due to the influence of the metallic iron on the molecules of prussian blue around it.

In another experiment, made with a view of observing the action of the magnetism of the earth on the phenomena observed in the experiments first mentioned, two slips of iron, A, B, similar to those used in the first experiment, were placed at right angles to and about an inch from each other. One was placed in a line with, and the other would of course be at right angles to, the magnetic meridian. The results produced were quite unexpected. Each slip of iron appeared to assume a polarity; the colour of the jelly became bleached in a circle round one-half of each slip of iron, and the colour so removed appeared to be deposited so as to form a thick coating on the other half of each slip, and after many months lines of colour extended from the centre of each slip of iron, forming a series of circular lines round the bleached area.



Experiments were made with slips of iron and copper, with iron and zinc, and with zinc and copper placed at a distance from each other, and the results showed that the one had a very marked action upon the other, although they were not in metallic contact. With zinc and copper bubbles of gas were developed from the zinc at the edge nearest to the copper slip, the bubbles forcing their way through the thick jelly from the centre of the edge of the zinc plate in nearly straight lines towards the copper, whilst the bubbles developed at other parts of the same edge of the zinc plate forced their way through the thick jelly in straight lines which, if prolonged, would all have met about the centre of the edge of the copper plate facing the zinc one. Gas was also simultaneously developed at the edge of the copper plate opposite the zinc one. From the copper, however, the gas did not develope in lines, but in a circular form beginning from the centre of the copper slip and gradually extending outwards towards the zinc.

Other experiments with slips of copper and iron, similarly placed at a distance from each other of about an inch, also showed a marked action upon each other by the lines of prussian blue molecules which flowed from them. These lines flowed from the one metal to the other. They did not, however, go by what one would take to be the directions of least resistance, but flowing away from the opposite metals they swept round the outside, and then turned inwards as if the lines from the two metals would join; but the glass plates not being large enough, they stopped at the margin of the coloured jelly. One curious result observed in those lines was the formation of eddies; one line of colour developed from the metal going, for instance, in the opposite direction to the hands of a clock, suddenly ended in an eddy, whilst another line flowing from the eddy formed part of a circle going in the opposite direction.

A number of experiments were made by placing discs of the same thin iron ·0075 inch thick × ·67 inch diameter on paper coloured with prussian blue lying on the top of wet blotting-paper, the whole being enclosed between two plates of glass and immersed in pure water. The blue colour on the paper gradually became bleached in a remarkable manner; the bleaching seemed to take place round the iron in an elliptical form, the iron disc being, roughly speaking, in the position of one of the foci of the ellipse, and ultimately the whole of the paper became bleached. In two experiments after bleaching the author removed the top glass. In the first there formed, immediately the air touched the surface of the bleached paper, a deep blue spot about half a diameter from the disc, and the whole of the paper then gradually became of a slate blue colour. In the second an irregularly round deep blue spot made its appearance the instant the top glass was removed, and the paper then gradually became blue. Thus it would appear as if the discs of

metallic iron exercised some influence on the deoxised molecules of the colour at some distance from them.

Other similar experiments were made, in which the glass plates with the disc on the prussian blue paper were allowed to remain for a much longer time after bleaching of the prussian blue had taken place, when black oxide of iron was gradually formed round the iron discs in a remarkable manner, with alternate rings of the black oxide and the bleached paper upon which no black oxide was deposited.

In one of these experiments there was produced a distinct ring of black oxide of iron at a distance of exactly half the diameter of the iron disc from it, the ring being precisely the same diameter as the disc employed.

This circle was produced as distinctly as if it had been drawn in ink by compasses, but the ring was thicker next the disc. Some months afterwards this ring almost faded away.

Experiments were made with lead discs on paper coloured with chromate of lead, but no apparent action was produced on the colouring material.

Glycerine jelly may thus be used for studying the influence of one metal on another at a distance from it, or of one piece of metal on another piece of the same kind, through the medium of the materials in which they are immersed, and also for the further study of some of the interesting phenomena mentioned herein.

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11. *On the Teaching of Chemistry in Elementary Schools.* *By* WM. LANT CARPENTER, *B.A.*, *B.Sc.*, *F.C.S.*

At a recent meeting of the Physical Society the author brought forward the system of science demonstration in elementary schools, as practised now for some years in Liverpool and Birmingham. This paper appeared in full in the midmonthly July supplement of the 'Journal of Education.' The essence of the system is the employment of a specially appointed expert, who goes from school to school with his apparatus, repeating the same lesson in each. The lessons are entirely oral; no textbooks are used; and the pupils write notes, which are revised by the demonstrator. Some of the results of the general system are communicated in a paper to Section F.

In Birmingham a very good central laboratory has recently been erected, where the stock of apparatus necessary for the lessons in elementary physics is kept, and it has also been fitted up for instruction of a somewhat more advanced character in physics and chemistry. A good deal of useful work has already been done here by the advanced pupils, and by some of the teachers, under the supervision of the senior demonstrator, Mr. W. Jerome Harrison, F.G.S. He has hardly commenced a general system of instruction in chemistry, analogous to that in physics, since chemistry for the first time now forms a part of the Government code. His idea of the proper system, however, is—

1. Attendance of the pupil at a course of elementary lectures, well illustrated, with *vivâ voce* examinations at the commencement of each lecture upon the subject of the preceding one.

2. A second course, consisting alternately of lectures and experimental work, the pupil in the latter performing for himself the experiments given in the former.

These two courses to be confined to the common elements and their compounds.

3. A third course, mainly experimental, and occupied more or less with the analysis of simple substances.

As at present with physics, the first of these courses would not be entered upon until the pupil had passed the fourth standard in the three R's. Great importance is attached by Mr. Harrison to the full reproduction of lectures in notes illustrated by rough sketches of apparatus, &c.

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12. *A new Method for Disinfecting Sewage and Recovering Ammonia from it.* *By* J. BOYD KINNEAR.

Section C.—GEOLOGY.

President of the Section—Professor W. C. Williamson, LL.D., F.R.S.

THURSDAY, SEPTEMBER 20.

The President delivered the following Address:—

Much of the second decade of my life was spent in the practical pursuit of geology in the field, and throughout most of that period I enjoyed almost daily intercourse with William Smith, the father of English Geology; but in later years circumstances restricted my studies to the Palæontological side of the science. Hence I was anxious that the Council of the British Association should place in this chair some one more familiar than myself with the later developments of geographical geology. But my friend, Professor Bonney, failing to recognise the force of my objections, intimated to me that I might render some service to the Association by putting before you a sketch of the present state of our knowledge of the vegetation of the Carboniferous Age.

This being a subject respecting which I have formed some definite opinions I am about to act upon the suggestion. To some this may savour of 'shop-talk.' But such is often the only talk which a man can indulge in intelligently, and to close his mouth on his special themes may compel him either to talk nonsense, or to be silent.

Whilst undertaking this task I am alive to the difficulties which surround it; especially those arising from the wide differences of opinion amongst palæobotanists on some fundamental points. On some of the most important of these there is a substantial agreement between the English and German palæontologists. The dissentients are chiefly, though not exclusively, to be found amongst those of France who have, in my humble opinion, been unduly influenced by what is in itself a noble motive—viz. a strong reverence for the views of their illustrious teacher, the late Adolphe Brongniart. Such a tendency speaks well for their hearts, though it may, in these days of rapid scientific progress, seriously mislead their heads. I shall, however, endeavour to put before you faithfully the views entertained by my distinguished French friends M. Renault, M. Grand-Eury, and the Marquis of Saporta, giving, at the same time, what I deem to be good reasons for not agreeing with them. I believe that many of our disagreements arise from geological differences between the French Carboniferous strata and those of our own islands. There are some important types of Carboniferous plants that appear to be much better represented amongst us than in France. Hence we have, I believe, more abundant material than the French palæontologists possess for arriving at sound conclusions respecting these plants. We have rich mines, supplying specimens in which the internal organisation is preserved, in Eastern Lancashire and Western Yorkshire, Arran, Burntisland, and other scattered localities. France has equally rich localities at Autun and St. Etienne. But some important difference exists between these localities. The French objects are preserved in an impracticable siliceous matrix, extremely troublesome to work, except in specimens of small size. Ours, on the other hand, are chiefly embedded in a calcareous material which, whilst it preserves the objects in an exquisite manner, does not prevent our dissecting examples of considerable magnitude. But,

besides this, we are much richer in huge Lepidodendroid and Sigillarian trees, with their Stigmarian roots, than the French are; hence we have a vast mass of material, illustrating the history of these types of vegetation, in which they seem to be seriously deficient. This fact alone appears to me sufficient to account for many of the wide differences of opinion that exist between us respecting these trees. My second difficulty springs out of the imperfect state of our knowledge of the subject. One prominent cause of this imperfection lies in the state in which our specimens are found. They are not only too frequently fragmentary, but most of those fragments only present the external forms of the objects. Now, mere external forms of fossil plants are somewhat like similarities of sound in the comparative study of languages. They are too often unsafe guides. On the other hand, microscopic internal organisations in the former subjects are like grammatical identities in the latter one. They indicate deep affinities that promise to guide the student safely to philosophical conclusions. But the common state in which our fossil plants are preserved presents a source of error that is positive as well as negative. Most of those from our coal-measures consist of inorganic shale, sandstone or ironstone, invested by a very thin layer of structureless coal. The surface of the inorganic substance is moulded into some special form dependent upon structural peculiarities of the living plants, which structures were sometimes external, sometimes internal, and sometimes intermediate ones. Upon this inorganic cast we find the thin film of structureless coal, which, though of organic origin, is practically as inorganic as the clay or sandstone which it invests; but its surface displays specific sculpturings which are apt to be regarded as always representing the outermost surface of the plant when living, whereas this is not always the case. That the coally film is a relic of the carbonaceous substance of the living plant is unquestionable; but the thinnest of these films are often the sole remaining representatives of structures that must originally have been many inches, and in some instances even many feet, in thickness. In such cases most of the organic material has been dissipated, and what little remains has often been so reconsolidated as to be merely moulded upon the sculptured inorganic substance which it covers, hence it affords no information respecting the exterior of the fossil when a living organism. It is, in my opinion, specimens like these that have caused the smooth bark of the Calamite to be credited with a fluted surface, and the Trigonocarpons with a simply triangular exterior and a misleading name, as it long caused the inorganic casts known as Sternbergiæ to be deemed a strange form of plant that had no representative amongst living types. In other cases the outermost surface of the bark is brought into close contact with the corresponding surface of the internal vascular cylinder. I have a Stigmaria in which the bases of the rootlets appear to be planted directly upon that cylinder, the whole of the thick intermediate bark having disappeared. In other examples that vascular zone has also gone. Thus the innermost and outermost surfaces of a cylinder, originally many inches apart, are, through the disappearance of the intermediate structures, brought into close approximation. In such cases, leaves and other external appendages appear to spring directly from what is merely an inorganic cast of the interior of the pith. I believe that many of our Calamites are in this condition. Such examples have suggested the erroneous idea that their characteristic longitudinal flutings belong to the exterior of the bark.

Fungi.—Entering upon a more detailed review of our knowledge of the Carboniferous plants, and commencing at the bottom of the scale, we come to the lowly group of the Fungi, which are unquestionably represented by the *Peronosporites antiquarius*[1] of Worthington Smith. There seems little reason for doubting that this is one of the Phycomycetous Fungi, possibly somewhat allied to the *Saprolegnieæ*; but since we have, as yet, no evidence respecting its fructification, these exact relationships must, for the present, remain undetermined. So far as I know, this is the only Fungus satisfactorily proved to exist in the Carboniferous rocks, unless the *Excipulites Neesii* of Goeppert and one or two allied forms belong to the Fungoid group. The *Polyporites Bowmanni* is unquestionably a scale of a Holoptychian fish.

[1] *Memoir* xi. p. 299.

Algæ.—Numerous objects supposed to belong to this family have been discovered in much older rocks than Carboniferous ones. The subject is a thorny one. That marine plants of some kind must have existed, simultaneously with the molluscous and other plant-eating animals of palæozoic times, is obviously indisputable. But what those plants were is another question. The widest differences of opinion exist in reference to many of them. A considerable number of those recognised by Schimper, Saporta, and other palæobotanists, are declared by Nathorst to be merely inorganic tracks of marine animals; and in the case of many of these I have little doubt that the Swedish geologist is right. Others have been shown to be imperfectly preserved fragments of plants of much higher organisation than Algæ; branches of Conifers even being included amongst them. I have as yet seen none of Carboniferous age that could be indisputably identified with the family of Algæ, though there are many that look like, and may probably be, such. The microscope alone can settle this question, though even this instrument fails to secure unity of opinion in the case of Dawson's *Prototaxites*; and no other of the supposed seaweeds, hitherto discovered, have been sufficiently well preserved to bear the microscopic test; hence I think that their existence in Carboniferous rocks can only be regarded as an unproven probability. Mere superficial resemblances do not satisfy the severe demands of modern science, and probabilities are an insufficient foundation upon which to build evolutionary theories.

Seeing what extremely delicate cell-structures *are* preserved in the Carboniferous beds, it cannot appear other than strange that the few imperfect Fungoid relics, just referred to, constitute the only terrestrial cellular Cryptogams that have been discovered in the Carboniferous strata. The Darwinian doctrine would suggest that these lower forms of plant-life ought to have abounded in that primæval age; and that they were capable of being preserved is proved by the numerous specimens met with in Tertiary deposits. Why we do not find such in the Palæozoic beds is still an unsolved problem.

Vascular Cryptogams.—The Vascular Cryptogams, next to be considered, burst upon us almost suddenly, and in rich profusion, during the Devonian age; they are silent equally in the Devonian and Carboniferous strata as to their ancestral descent.

Ferns.—The older taxonomic literature of Palæozoic Fern-life is, with few exceptions, of little scientific value. Hooker and others have uttered in vain wise protests against the system that has been pursued. Small fragments have had generic and specific names assigned to them, with supreme indifference to the study of morphological variability amongst living types. The undifferentiated tip of a terminal pinnule has had its special name, whilst the more developed structures forming the lower part of a frond have supplied two or three more species. Whilst the distinct forms of the sterile and fertile fronds may have furnished additional ones, a further cause of confusion is seen in the wide difference existing between a young, half-developed seedling and the same plant at an advanced stage of its growth. Anyone who has watched the growth of a young *Polypodium aureum* can appreciate this difference. Yet, in the early stages of palæontological research, observers could scarcely have acted otherwise than as they did in assigning names to these fragments, if only for temporary working purposes. Our error lies in misunderstanding the true value of such names. At present the study of fossil ferns is affording some promise of a newer and healthier condition. We are slowly learning a little about the fructification of some species, and the internal organisation of others. Such facts, cautiously interpreted, are surer guides than mere external contours; unfortunately, such facts are, as yet, but few in number, and when we have them we are too often unable to identify our detached sporangia, stems, and petioles with the fronds of the plants to which they primarily belonged.

That all the Carboniferous plants included in the genera *Pecopteris, Neuropteris,* and *Sphenopteris* are ferns appears to be most probable; but what the true affinities of the objects included in these ill-defined genera may be is very doubtful. Here and there we obtain glimpses of a more definite kind. That the Devonian *Palæopteris Hibernica* is a Hymenophyllous form appears to be almost certain;

and, on corresponding grounds, we may conclude that the Carboniferous forms, *Sphenopteris trichomanoides*, *S. Humboltii*,[1] and *Hymenophyllum Weissii*,[2] belong to the same group. The fructification of the two latter leaves little room for doubting their position, whilst the foliage of some other species of Sphenopteris is suggestive of similar conclusions; but until their fructification is discovered this cannot be determined. An elegant form of Sphenopteris (*S. tenella* Brong., *S. lanceolata* of Gutbier), recently described by Mr. Kidson of Stirling, abundantly justifies caution in dealing with these Sphenopterides. This plant possesses a true Sphenopteroid foliage, but its fructification is that of a Marattiaceous *Danaid.* The sporangia are elongated vertically, and have the round terminal aperture of both the recent and fossil *Danaiæ*—a group of plants far removed from the Hymenophyllaceous type of Sphenopterid already referred to.

Whether or not this *Sphenopteris* was really Marattiaceous in other features than its fructification is uncertain; but I think that we have indisputably obtained stems and petioles of Marattiaceæ from the Carboniferous strata. My friend M. Renault and I, without being aware of the fact, simultaneously studied the *Medullosa elegans* of Cotta. This plant was long regarded as the stem of a true Monocotyledon, a decision the accuracy of which was doubted, first by Brongniart and afterwards by Binney. M. Renault's memoir and my memoir, part vii. appeared almost simultaneously. We then found that we had alike determined the supposed Monocotyledon not only to be a fern, but to belong to the peculiarly aberrant group of the *Marattiaceæ.* As yet we know nothing of its foliage and fructification.

M. Grand-Eury has figured [3] a remarkable series of ferns from the coal-measures of the basin of the Loire, the sporangia of which exhibit marked resemblances to those of the Marattiaceæ. This is especially the case with his specimens of *Asterotheca* and *Scolecopteris*,[4] as also with his *Pecopteris Marattiætheca*, *P. Angiotheca*, and *P. Danaeætheca*; but there is some doubt as to the dehiscence of the sporangia of these places; hence their Marattiaceous character is not absolutely established.

That the coal-measures contain the remains of arborescent ferns has long been known, especially from their abundance at Autun. In Lancashire I have only met with the stems or petioles of one species preserving their internal organisation.[5] The Rev. H. H. Higgins obtained stems that appear to have been tree-ferns from Ravenhead, in Lancashire, and it is probable that most of the plants included in the genera *Psaronius*, *Caulopteris*, and *Protopteris* are also tree-ferns.

There yet remains another remarkable group of ferns, the sporangia of which are known to us through the researches of M. Renault. In these the fertile pinnules are more or less completely transmuted into small clusters of oblong sporangia. In one case M. Renault believes that he has identified these organs with a stem or petiole of a type not uncommon at Oldham and Halifax, belonging to Corda's genus Zygopteris. Renault has combined this with some others to constitute his group of *Botryopteridées*, an altogether extinct and generalised type. This review shows that whilst forms identifiable with the *Hymenophyllaceæ* and *Marattiaceæ* existed in the Carboniferous epoch, and we find here and there traces of affinities with some other more recent types, most of the Carboniferous ferns are generalised primæval forms, which only became differentiated into later ones during the slow progress of time.

Equisetaceæ and *Asterophylliteæ*, Brong. *Calamariæ*, Endlicher. *Equisetineæ*, Schimper.

Confusion culminates in the history of this variously-named group. Hence the subject is a most difficult one to treat in a concise way. The confusion began

[1] *Schimper*, vol. i. p. 408. [2] *Ibid.* p. 415.

[3] *Flore Carbonifère du Département de la Loire et du centre de la France.*

[4] *Loc. cit.* Tab. viii. figs. 1–5.

[5] Psaronius Renaultii, *Memoir* vii. p. 10, and *Memoir* xii. Pl. iv. fig. 16. These and other similar references are to my series of Memoirs 'On the Organisation of the Fossil Plants of the Coal-measures,' published in the *Philosophical Transactions*.

when Brongniart separated the plants contained in the group into two divisions—one of which (*Équisétacées*) he identified with the living Equisetums, and the other (*Astérophyllitées*) he regarded as being Gymnospermous Dicotyledons. To Schimper belongs the merit, as I believe it to be, of steadily resisting this division; nevertheless, palæobotanists are still separated into two schools on the subject; Renault, Grand-Eury, and Saporta adhere more or less closely to the Brongniartian idea, whilst the British and German palæontologists have always rejected the idea that any of these plants were other than Cryptogams.

A fundamental feature of the entire group is seen in their foliar appendages, which, however morphologically and physiologically modified, are arranged in nodal verticils. This appears to be the only characteristic which the plants possess in common.

Calamites and Calamodendron. In his 'Prodrome' (1828), and in his later 'Vegetaux Fossiles,' Brongniart adopted the former of these generic names as previously employed by Suckow, Schlotheim, Sternberg, and Artis. It was only in his 'Tableau des Genres de Vegetaux Fossiles' (*Dictionnaire universel d'Histoire Naturelle*, 1849) that he divided the genus, introducing the name of Calamodendron to represent what he believed to be the Gymnospermous division of the group. A long series of investigations, extending over many years, has convinced me that no such Gymnospermous type exists.[1] The same conclusion has more recently been arrived at by Vom c. M. D. Stur,[2] after studying many continental examples in which structure is preserved. What I regard as an error appears to have had an intelligible origin—the fertile source of similar errors in other groups.

Nearly all the Calamitean fossils found in shales and sandstones consist of an inorganic, superficially fluted substance, coated over with a thin film of structureless coal. (See *Histoire des Végétaux Fossiles*, Vol. i., Pl. 22), *the latter being exactly moulded upon and retaining the outlines of the inorganic fluted cast that underlies it.* Brongniart and those who adopt his views, believe that the external surface of this coal-film exactly represents the corresponding external surface of the original plant. Hence the conclusion was arrived at that the plant had a very large central fistular cavity, surrounded by a very thin layer of cellular and vascular tissues, as in some living Equisetums. On the other hand, Brongniart also obtained some specimens of what he primarily believed to be Calamites, in which the central pith was surrounded by a thick layer of vascular tissue arranged in radiating laminated wedges, separated by medullary rays. The Exogenous structure of this vascular zone was too obvious to escape his practised eye. But, not supposing it possible that any Cryptogam could possess a cambium-layer and an Exogenous mode of development, Brongniart came to the conclusion that whilst the thin-walled specimens found in the shales and sandstones were true *Equisetaceæ*, those with the thick woody cylinders were Exogens of another type. His conclusion that they were Gymnosperms was a purely hypothetical one, justified by no one feature of their organisation.

My researches, based upon a vast number of specimens of all sizes, from minute twigs, little more than the thirtieth of an inch in diameter, to thick stems at least thirteen inches across, soon led me to the conclusion that we have but one type of Calamite; and that the differences which misled Brongniart are merely due to variations in the mode of their preservation.[3] It became clear to me that the outer surface of the coally film in the specimens preserved in the shales and sandstones, did *not* represent the outer surface of the living plant, but was only a fractional remnant of the original carbon of that plant which had undergone a complete metamorphosis; the greater part of what primarily existed had disappeared, probably in a gaseous state; and the little that remained, displaying no organic structure, *had been moulded upon the underlying inorganic cast of the medullary cavity.* This cast is always fluted longitudinally and constricted transversely at intervals of varying lengths. Both these features were due to impressions made by the organism upon the inorganic sand or mud introduced into the

[1] *Memoirs* i. ix. and xii. [2] *Zur Morphologie der Calamarien.*
[3] *Memoirs* i. and ix.

medullary cavity whilst it was in a plastic state, but which plastic material subsequently became more or less hardened; its longitudinal grooves being caused by the pressure of the inner angles of the numerous longitudinal vascular wedges, and the transverse ones, partly by the remains of a cellular nodal diaphragm which crossed the fistular medullary cavity, and partly by a centripetal encroachment of the vascular zone at each corresponding point.[1]

My cabinets contain an enormous number of sections of these plants in which the minutest details of their organisation are exquisitely preserved. These specimens, as already observed, show their structure in every stage of their growth, from the minutest twigs to stems more than a foot in diameter. Yet these various examples are all, without a solitary exception, constructed upon one common plan. That plan is an extremely complicated one; far too complex to make it in the slightest degree probable that it could co-exist in two such very different orders of plants as the *Equisetaceæ* and the *Gymnospermæ*; yet, though very complex, it is, even in many of its minuter details, unmistakably the plan upon which the living Equisetums are constructed. The resemblances are too clear as well as too remarkable, in my mind, to leave room for any doubt on this point. The great differences are only such as necessarily resulted from the gradual attainment of the arborescent form, so unlike the lowly herbaceous one of their living representatives. On the other hand, no living Gymnosperm possesses an organisation that *in any solitary feature* resembles that of the so-called Calamodendra. The two have absolutely nothing in common; hence the conclusion that these Calamodendra were Gymnospermous plants, is as arbitrary an assumption as could possibly be forced upon science; an assumption that no arguments derived from the merely external aspects of structureless specimens could ever induce me to accept.

These Calamites exhibit a remarkable morphological characteristic which presents itself to us here for the first time, but which we shall find recurs in other Palæozoic forms. Some of our French botanical friends group the various structures contained in plants into several '*Appareils*,'[2] distinguished by the functions which those structures have to perform. Amongst others we find the '*Appareil de soutiens*' embracing those hard woody tissues which may be regarded as the supporting skeleton of the plant, and the '*Appareil conducteur*' which M. Van Tieghem describes as composed of two tissues: 'Le tissu criblé qui transporte essentiellement les matières insolubles, et le tissu vasculaire qui conduit l'eau et les substances dissoutes.' Without discussing the scientific limits of this definition, it suffices for my present purpose. In nearly all flowering plants these two '*Appareils*' are more or less blended. The supporting wood cells are intermingled, in varying degrees, with the sap-conducting vessels. It is so even in the lower Gymnosperms, and in the higher ones these wood-cells almost entirely replace the vessels. It is altogether otherwise with the fossil Cryptogams. The vascular cylinder in the interior of the Calamites, for example, consists wholly of *barred* vessels, a slight modification of the scalariform type so common in all Cryptogams. No trace of the '*Appareil de soutiens*' is to be found amongst them. The vessels are, in the most definite sense, the '*Appareils conducteurs*' of these plants; no such absolutely undifferentiated unity of tissue is to be found in the vascular portions of any living plants other than Cryptogams.

But these Calamites, when living, towered high into the air. My friend and colleague, Professor Boyd Dawkins, recently assisted me in measuring one, found in the roof of the Moorside colliery near Ashton-under-Lyne by Mr. George Wild, the very intelligent manager of that and some neighbouring collieries. The flattened specimen ran obliquely along the roof, each of its two extremities passing out of sight by burying themselves in the opposite sides of the mine. Yet the portion which we measured was 30 feet long, its diameter being 6 inches at one end, and $4\frac{1}{2}$ inches at the other. The mean length of its internodes at its broader end was 3 inches, and at its narrower one $1\frac{1}{2}$ inches. What the real thickness of this specimen was when all its tissues were present, we have no means

[1] See *Memoir* i. Pl. xxiv. fig. 10, and Pl. xxvi. fig. 24.

[2] Van Tieghem, *Traité de Botanique*, p. 679.

of judging, but the true diameter of the cylinder represented by the fossil when uncompressed has been only 4 inches at one end of the 30 feet, and 2½ inches at the other. Whatever its entire diameter when living, the vascular cylinder of this stem must have been at once tall and slender, and consequently must have required some '*Appareil de soutien*,' such as its exogenous vascular zone did not supply. This was provided, in a very early stage of growth, by the introduction of a second cambium-layer into the bark; which, though reminding us of the cork-cambium in ordinary Exogenous stems, produced, not cork, but prosenchymatous cells.[1] In its youngest state the bark of the Calamites was a very loose cellular parenchyma, but in the older stems most of this parenchyma became enclosed in the prosenchymatous tissue referred to, which appears to have constituted the greater portion of the matured bark. The sustaining skeleton of the plant, therefore, was a hollow cylinder developed centrifugally on the inner side of an enclosing cambium-zone. That this cambium-zone must, in matured stems, have had some protective periderm external to it is obvious; but I have not yet discovered what it was like. We shall find a similar cortical provision for supporting lofty Cryptogamous stems in the *Lepidodendra* and *Sigillariæ*.

The Carboniferous rocks have furnished a large number of plants having their foliage arranged in verticils, and which have had a variety of generic names assigned to them; such are *Asterophyllites*, *Sphenophyllum*, *Annularia*, *Bechera*, *Hippurites*, and *Schizoneura*. Of these genera, *Sphenophyllum* is distinguished by the small number of its wedge-shaped leaves, and the structure of its stems has been described by M. Renault. *Annularia* is a peculiar form in which the leaves forming each verticil, instead of being all planted at the same angle upon the central stem, are flattened obliquely nearly in the plane of the stem itself. *Asterophyllites* differs from *Sphenophyllum*, chiefly in the larger number and in the linear form of its leaves. Some stems of this type have virtually the same structure[2] as those of *Sphenophyllum*, a structure which differs widely from that of the Calamites, and of which, consequently, these plants cannot constitute the leaf-bearing branches. But there is little doubt that true Calamitean branches have been included in the genus *Asterophyllites*; I have specimens, for which I am indebted to Dr. Dawson, which I should unhesitatingly have designated *Asterophyllites*, but for my friend's positive statement that he detached them from stems of a Calamite. Of the internal organisation of the stems of the other genera named, we know nothing.

It is a remarkable fact that, notwithstanding the number of young Calamitean shoots obtained from Oldham and Halifax, in which all the tissues are preserved, we have not met with one with attached leaves. This is apparently due to the fact that most of the specimens are decorticated. We have a sufficient number of corticated specimens to show us what the bark was, but such specimens are very rare. They clearly prove, however, that their bark had a smooth, and not a furrowed, external surface.

There yet remain for consideration the numerous reproductive strobili, generally regarded as belonging to plants of this class of *Equisetinæ*. We find some of these strobili associated with stems and foliage of known types, as in *Sphenophyllum*,[3] but we know nothing of the internal organisation of these Sphenophylloid strobili. We have strobili connected with stems and foliage of *Annularia*,[4] but we are equally ignorant of the organisation of these; so far as that organisation can be ascertained from Sterzel's specimen, it seems to have alternating sterile and fertile bracts, with the sporangia of the latter arranged in fours, as in *Calamostachys*.[5] On the other hand, we are now very familiar with the structure of the *Calamostachys Binneana*, the prevalent strobilus in the calcareous nodules found in the lower coal-measures of Lancashire and Yorkshire. It has evidently been a sessile spike,

[1] *Memoir* ix. Pl. xx. figs. 14, 15, 18, 19, and 20.
[2] *Memoir* v. Plates i.–v. and ix. Pl. xxi. fig. 32.
[3] Lesquereux, *Coal Flora of Pennsylvania*, Pl. ii. fig. 687.
[4] 'Ueber die Fruchtähren von Annularia Sphenophylloides.' Von T. Sterzel, *Zeitschr. d. Deutschen Geolog. Gesellschaft*, Jahrg. 1882.
[5] M. Renault has described a strobilus under the name of *Annularia longifolia*, but which appears to me very distinct from that genus.

the axial structures of which were trimerous[1] (rarely tetramerous), having a cellular medulla in its centre. Its appendages were exact multiples of those numbers. Of the plant to which it belonged, we know nothing. On the other hand, we have examples, supposed to be of the same genus, as *C. paniculata*,[2] and *C. polystachya*,[3] united to stems with Asterophyllitean leaves, but whether or not these fruits had the organisation of *C. Binneana*, we are unable to say.

We are also acquainted with the structure of the two fruits belonging to the genera *Bruckmannia*[4] and *Volkmannia*.[5] This latter term has long been very vaguely applied.

There still remain the genera *Stachannularia*, *Palæostachya*, *Macrostachya*, *Cingularia*, *Huttonia*, and *Calamitina*, all of which have the phyllomes of their strobili, fertile and sterile, arranged in verticils, and some of them display Asterophyllitean foliage. But these plants are only known from structureless impressions. That all these curious spore-bearing organisms have close affinities with the large group of the Equisetums, cannot be regarded as certain, but several of them undoubtedly have peculiarities of structure suggestive of relations with the Calamites. This is especially observable in the longitudinal canals found in the central axis of some types, apparently identical with what I have designated the internodal canals of the Calamites.[6] The position and structure of their vascular bundles suggest the same relationship, whilst in many the positions of the sporangia and sporangiophores are eminently Equisetiform. Renault's *Bruckmannia Grand-Euryi* and *B. Decaisnei*, as well as a strobilus which I described in 1870,[7] exhibit these Calamitean affinities very distinctly.

One strobilus which I described in 1880[8] must not be overlooked. As is well known, all the living forms of Equisetaceous plants are isosporous. We only discover heterosporous vascular Cryptogams amongst the *Lycopodiaceæ* and the *Rhizocarpæ*. My strobilus is identical in every detailed feature of its organisation with the common *Calamostachys Binneana*, excepting that it is heterosporous, having microspores in its upper and macrospores in its lower part; a state of things suggestive of some link between the *Equisetinæ* and the heterosporous *Lycopodiaceæ*.

Lycopodiaceæ.—This branch of my subject suggests memories of a long conflict which, though virtually over, still leaves, here and there, the ground-swell of a stormy past. At the meeting of the British Association at Liverpool, in 1870, I first announced that a thick, secondary, exogenous growth of vascular tissue existed in the stems of many Carboniferous Cryptogamic plants, especially in the Calamitean and Lepidodendroid forms. But, at that time, the ideas of M. Brongniart were so entirely in the ascendant, that my notions were rejected by every botanist present. Though the illustrious French palæontologist knew that such growths existed in *Sigillariæ* and in what he designated *Calamodendra*, he concluded that, *de facto*, such plants could not be Cryptogams. Time, however, works wonders. Evidence has gradually accumulated proving that—with the conspicuous exception of the ferns—nearly every Carboniferous Cryptogam was capable of developing such zones of secondary growth. The exceptional position of the ferns still appears to be as true as it was when I first proclaimed their exceptional character at Liverpool. At that time I was under the impression that the secondary wood was only developed in such plants as attained to arboreal dimensions, but I soon afterwards

[1] It is an interesting fact that transverse sections of the strobili of Lycopodium Alpinum exhibit a somewhat similar trimerous arrangement, though differing widely in the positions of its sporangia.

[2] Weiss, *Abhandlungen zur Geologischen Specialkarte von Preuszen und Thüringischen Staaten*, Taf. xiii. Fig. 1.

[3] *Idem.* Taf. xvi. Fig. 1, 2.

[4] Renault. *Annales de Sciences naturelles.* Bot. Tome iii. Pl. iii.

[5] *Idem.* Pl. ii.

[6] *Memoir* i. Pl. xxiii. Fig. 1 e, and Pl. xxv. Fig. 20 e.

[7] *Memoirs of the Literary and Philosophical Society of Manchester*, 3rd series, vol. iv. p. 248.

[8] *Memoir* xi. Pl. liv. figs. 23, 24.

discovered that it occurred equally in many small plants like *Sphenophyllum*, *Asterophyllites* and other more diminutive types.

After thirteen years of persevering demonstration, these views, at first so strongly opposed, have found almost universal acceptance. Nevertheless, there still remain some few who believe them to be erroneous. In the later stages of this discussion the botanical relations subsisting between *Lepidodendron*, *Sigillaria*, and *Stigmaria* have been the chief themes of debate. In this country we regard the conclusion that *Stigmaria* is not only a root, but the root alike of *Lepidodendron* and *Sigillaria*, as settled beyond all dispute. Nevertheless M. Renault and M. Grand-Eury believe that it is frequently a leaf-bearing rhizome, from which aerial stems are sent upwards. I am satisfied that there is not a shadow of foundation for such a belief. The same authors, along with their distinguished countryman, the Marquis of Saporta, believe, with Brongniart, that it is possible to separate *Sigillaria* widely from *Lepidodendron*. They leave the latter plant amongst the *Lycopods*, and elevate the former to the rank of a Gymnospermous Exogen. I have demonstrated in vain the existence of a large series of specimens of the same species of plant, young states of which display all the essential features of structure which they believe to characterise *Lepidodendron*, whilst in its progress to maturity, every stage in the development of the secondary wood, regarded by them as characteristic of a *Sigillaria*, can be followed step by step.[1] Nay, more: my cabinet contains specimens of young dichotomously branching twigs, in which one of the two diverging branches has only the centripetal cylinder of the *Lepidodendron*, whilst the other has begun to develop the secondary wood of the *Sigillaria*.[2]

The distinguished botanist of the Institut, Professor Ph. van Tieghem, has recently paid some attention to the conclusions adopted by his three countrymen in this controversy, and has made an important advance upon those conclusions, in what I believe to be the right direction. He recognises the Lycopodiaceous character of the *Sigillariæ*, and their close relations to the *Lepidodendra*;[3] and he also accepts my demonstration of the unipolar, and consequently Lycopodiaceous, character of the fibro-vascular bundle of the Stigmarian rootlet, a peculiarity of structure of which M. Renault has hithero denied the existence. But, along with these recognitions of the accuracy of my conclusions, he gives fresh currency to several of the old errors relating to parts of the subject to which he has not yet given personal attention. Thus he considers that the *Sigillariæ*, though closely allied to the *Lepidodendra*, are distinguished from them by possessing the power of developing the centrifugal or exogenous zone of vascular tissue already referred to. He characterises the *Lepidodendra* as having '*un seul bois centripète*,' notwithstanding the absolute demonstrations to the contrary contained in my Memoir xi. Dealing with the root of *Sigillaria*, which in Great Britain at least is the well-known *Stigmaria ficoides*, following Renault, he designates it a '*rhizome*,' limiting the term root to what we designate the rootlets. He says, 'Le rhizome des Sigillaires a la même structure que la tige aérienne, avec des bois primaires tantôt isolés à la périphérie de la moelle, tantôt confluents au centre et en un axe plein; seulement les fasceaux libéro-ligneux secondaires y sont séparés par de plus larges rayons,' &c.

Now, *Stigmaria* being a root, and not a rhizome, contains no representative of the primary wood of the stem. This latter is, as even M. Brongniart so correctly pointed out long ago, the representative of the medullary sheath, and the fibro-vascular bundles which it gives off are all foliar ones, as is the case with the bundles given off by this sheath in all Exogenous plants. But in the *Lepidodendra* and *Sigillariæ*, as in all living exogens, it is not prolonged into the root. In the latter, as might be expected *à priori*, we only find the secondary, or exogenous, vascular zone. Having probably the largest collection of sections of *Stigmariæ* in the world, I speak unhesitatingly on these points. M. van Tieghem further says, 'La tige aérienne part d'un rhizome rameux très-développé nommé *Stigmaria*, sur lequel s'insèrent à la fois de petites feuilles et des racines parfois dichotomées.' I have yet to see a solitary fact justifying the statement that leaves are intermingled with the rootlets of

[1] *Memoir* xi. Plates xlvii.–lii. [2] *Idem*. Pl. xlix. fig. 8.
[3] *Traité de Botanique*, p. 1304.

Stigmaria. The statement rests upon an entire misinterpretation of sections of the fibro-vascular bundles supplying those rootlets and an ignorance of the nature and positions of the rootletst, hemselves. More than forty years have elapsed since John Eddowes Bowman first demonstrated that the *Stigmariæ* were true roots, and every subsequent British student has confirmed Bowman's accurate determination.

M. Lesquereux informs me that his American experiences have convinced him that *Sigillaria* is Lycopodiaceous. Dr. Dawson has now progressed so far in the same direction as to believe that there exists a series of Sigillarian forms, which link the *Lepidodendra* on the one hand with the Gymnospermous exogens on the other. As an evolutionist I am prepared to accept the possibility that such links may exist. They certainly do, so far as the union of *Lepidodendron* with *Sigillaria* is concerned. I have not yet seen any from the higher part of this chain that are absolutely satisfactory to me, but Dr. Dawson thinks that he has found such. I may add that Schimper, and the younger German school, have always associated *Sigillaria* with the *Lycopodiaceæ.* But there are yet other points under discussion connected with these fossil Lycopods.

M. Renault affirms that some forms of *Halonia* are subterranean rhizomes, and the late Mr. Binney believed that *Haloniæ* were the roots of *Lepidodendron.* I am not acquainted with a solitary fact justifying either of these suppositions, and unhesitatingly reject them. We have the clearest evidence that some *Haloniæ* at least are true terminal, and, as I believe, strobilus-bearing, branches of various Lepidodendroid plants; and I see no reason whatever for separating *Halonia regularis* from those whose fruit-bearing character is absolutely determined. Its branches, like the others, are covered throughout their entire circumference, and in the most regularly symmetrical manner, with leaf-scars, a feature wholly incompatible with the idea of the plant being either a root or a rhizome. M. Renault has been partly led astray in this matter by misinterpreting a figure of a specimen published by the late Mr. Binney. That specimen being now in the museum of Owens College, we are able to demonstrate that it has none of the features which M. Renault assigns to it.

The large round or oval, distichously-arranged, scars of *Ulodendron* have long stimulated discussion as to their nature. This, too, is now a well-understood matter. Lindley and Hutton long ago suggested that they were scars whence cones had been detached; a conclusion which was subsequently sustained by Dr. Dawson and Schimper, and which structural evidence led me also to support.[1] The matter was set at rest by Mr. d'Arcy Thompson's discovery of specimens with the strobili *in situ.* Only a small central part of the conspicuous cicatrix characterising the genus represented the area of organic union of the cone to the stem. The greater part of that cicatrix has been covered with foliage, which, owing to the shortness of the cone-bearing branch, was compressed by the base of the cone. The large size of many of these biserial cicatrices on old stems, has been due to the considerable growth of the stem subsequently to the fall of the cone.

Our knowledge of the terminal branches of the large-ribbed *Sigillariæ* is still very imperfect. Palæontologists who have urged the separation of the *Sigillariæ* from the *Lepidodendra* have attached weight to the difference between the longitudinally-ridged and furrowed external bark of the former plants, along which ridges the leaf-scars are disposed in vertical lines, and the diagonally-arranged scars of *Lepidodendron.* They have also dwelt upon the alleged absence of branches from the Sigillarian stems. I think that their mistake, so far as the branching is concerned, has arisen from their expectation that the branches must necessarily have had the vertically-grooved appearance and the longitudinal arrangement of the leaf-scars, observed in the more aged trunks; hence they have probably seen the branches of *Sigillariæ* without recognising them. I believe this to have been the case. I further entertain the belief that the transition from the *vertical* phyllotaxis, or leaf-arrangement, of the Sigillarian leaf-scars, to the *diagonal* one of the *Lepidodendra,* will ultimately be found to be effected through the sub-genus *Favularia,* in many forms of which this diagonal arrangement be-

[1] *Memoir* ii. p. 222.

comes quite as conspicuous as the vertical one. This is the case even in Brongniart's classic specimen of *Sigillaria elegans*, long the only fragment of that genus known which retained its internal structure. The fact is, the shape of the leaf-scars, as well as the degree of their proximity to each other, underwent great changes as Lepidodendroid and Sigillarian stems advanced from youth to age. Thus Presl's genus Bergeria was based on forms of Lepidodendroid scars which we now find on most of the terminal branches of unmistakable *Lepidodendra*.[1] The phyllotaxis of *Sigillaria*, of the type of *S. occulata*, passes by imperceptible gradations into that of *Favularia*. In many young branches the leaves were densely crowded together; but the exogenous development of the interior of the stem, and its consequent growth both in length and thickness, pushed these scars apart at the same time that it increased their size and altered their shape. We see precisely the same effects produced by the same causes upon the large fruit-scars of Ulodendron. The Carboniferous Lycopods were mostly arborescent, but some few dwarf forms, apparently like the modern *Selaginellæ*, have been found in the Saarbrücken coal-fields. Many of the arborescent forms, if not all, produced secondary wood, by means of a cambium layer, as they increased in age. In the case of some of them [2] this was done in a very rudimentary manner, nevertheless sufficiently so to demonstrate what is essential to the matter, viz. the existence of a cambium layer producing a centrifugal growth of secondary vascular tissue.

As already pointed out in the case of the Calamites, the vascular axis of these *Lepidodendra* was purely an *appareil conducteur*, unmixed with any wood-cells; hence the *appareil de soutien* had to be supplied elsewhere. This was done in the same way as in the Calamites: a thick, persistent, hypodermal zone of meristem [3] developed a layer of prismatic prosenchyma of enormous thickness,[4] which encased the softer structures in a strong cylinder of self-supporting tissue. We have positive evidence that the fructification of many of these plants was in the form of heterosporous strobili. Whether or not such was the case with all these *Lepidostrobi* we are yet unable to determine. But the incalculable myriads of their macrospores, seen in so many coals, afford clear evidence that the heterosporous types must have preponderated vastly over all others.

Gymnosperms.—Our knowledge of this part of the Carboniferous vegetation has made great progress during the last thirty years. This progress began with my own discovery [5] that all our British *Dadoxylons* possessed what is termed a discoid pith, such as we see in the white Jasmine, some of the American hickories, and several other plants. At the same time I demonstrated that most of our objects hitherto known as *Artisias* and *Sternbergias* were merely inorganic casts of these discoid medullary cavities. Further knowledge of the genus *Dadoxylon* seems to suggest that it was not only the oldest of the true Conifers in point of time, but also one of the lowest of the coniferous types.

Cycads.—The combined labours of Grand-Eury, Brongniart, and Renault have revealed the unexpected predominance, in some localities, of a primitive but varied type of Cycadean vegetation. Observers have long been familiar with certain seeds known as *Trigonocarpons* and *Cardiocarpons*, and with large leaves to which the name of *Noeggerathia* was given by Sternberg. All these seeds and leaves have been tossed from family to family at the caprice of different classifiers, but in all cases without much knowledge on which to base their determinations. The rich mass of material disinterred by M. Grand-Eury at St. Etienne, and studied by

[1] See *Memoir* xii. Pl. xxxiv.

[2] *E.g.* L. Harcourtii, *Memoir* xi. Pl. xlix. fig. 11.

[3] *Memoir* ix. Pl. xxv. figs. 93, 94, 98, 99, 100, and 101.

[4] *Memoir* xi. Pl. xlviii. fig. 4 *f f′*. *Memoir* ii. Pl. xxix. fig. 42 *k*. *Memoir* iii. Pl. xliii. fig. 17.

[5] 'On the Structure and Affinities of the Plants hitherto known as Sternbergias,' *Memoirs of the Literary and Philosophical Society of Manchester*, 1851. M. Renault, in his *Structure comparée de quelques Tiges de la Flore Carbonifère*, p. 285, has erroneously attributed this discovery to Mr. Dawes, including my illustration from the Jasminium and Juglans. Mr. Dawes' explanation was a very different one.

Brongniart and M. Renault has thrown a flood of light upon some of these objects, which now prove to be primæval types of Cycadean vegetation.

Mr. Peach's discovery of a specimen demonstrating that the *Antholithes Pitcairniæ*[1] of Lindley and Hutton was not only, as these authors anticipated, 'the inflorescence of some plant,' but that its seeds were the well-known *Cardiocarpons*, was the first link in an important chain of new evidence. Then followed the rich discoveries at St. Etienne, where a profusion of seeds, displaying wonderfully their internal organisation, was brought to light by the energy of M. Grand-Eury, which seeds M. Brongniart soon pronounced to be Cycadean. At the same time I was obtaining many similar seeds from Oldham and Burntisland, in which also the minute organisation was preserved. Dawson, Newberry, and Lesquereux have also shown that many species of similar seeds, though retaining no traces of internal structure, occur in the coal-measures of North America.

Equally important was the further discovery, by M. Grand-Eury, that the *Antholithes*, with their Cardiocarpoid seeds, were but one form of the monoclinous catkin-like inflorescences of the *Noeggerathiæ*, now better known by Unger's name of *Cordaites*. These investigations suggest some important conclusions:—1st. The vast number and variety of these Cycadean seeds, as well as the enormous size of some of them, is remarkable, showing the existence of an abundant and important Carboniferous vegetation, of most of which no trace has yet been discovered other than these isolated seeds. 2nd. Most of the seeds exhibit the morphological peculiarity of having a large cavity (the "cavité pollinique' of Brongniart) between the upper end of the nucelle and its investing episperm, and immediately below the micropile of the seed. That this cavity was destined to have the pollen grains drawn into it, and be thus brought into direct connection with the apex of the nucelle, is shown by the various examples in which such grains are still found in that cavity.[2] 3rd. M. Grand-Eury has shown that some of his forms of *Cordaites* possessed the discoid or Sternbergian pith which I had previously found in *Dadoxylon*; and, lastly, these *Cordaites* prove that a diclinous form of vegetation existed at this early period in the history of the flowering plants, but whether in a monœcious or a diœcious form we have as yet no means of determining. Their reproductive structures differ widely from the true cones borne by most Cycads at the present day.

Conifers.—It has long been remarked that few real cones of Conifers have hitherto been found in the Carboniferous rocks, and I doubt if any such have yet been met with. Large quantities of the woody stems now known as *Dadoxylons* have been found both in Europe and America. These stems present a true coniferous structure both in the pith, medullary sheath wood, and bark.[3] The wood presents one very peculiar feature. Its foliar bundles, though in most other respects exactly like those of ordinary Conifers, are given off, not singly, but in pairs.[4] I have only found this arrangement of double foliar bundles in the Chinese Gingko (*Salisburia adiantifolia*).[5] This fact is not unimportant when connected with another one. Sir Joseph Hooker long ago expressed his opinion that the well-known *Trigonocarpons*[6] of the coal measures were the seeds of a Conifer allied to this *Salisburia*. The abundance of the fragments of *Dadoxylon*, combined with the readiness with which cones and seeds are preserved in a fossil state, make it probable that the fruits belonging to these woody stems would be so preserved. But of cones we find no trace, and, as we discover no other plant in the Carboniferous strata to which the *Trigonocarpons* could with any probability have belonged, these facts afford grounds for associating them with the *Dadoxylons*. These combined reasons, viz. the structure of the stems with their characteristic foliar bundles, and the Gingko-like character of the seeds, suggest the probability that these *Dadoxylons*,

[1] *Fossil Flora*, p. 82.

[2] *Memoir* viii. Pl. ii. figs. 70 and 72. Brongniart, *Recherches sur les Graines Fossiles Silicifiées*, Pl. xvi. figs. 1, 2; Pl. xx. fig. 2.

[3] Dr. Dawson finds the discoid pith in one of the living Canadian Conifers.

[4] *Memoir* viii. Pl. lviii. fig. 48, and Pl. ix. figs. 44–46.

[5] *Memoir* xii. Pl. xxxiii. figs. 28, 29.

[6] *Memoir* viii. figs. 94–115.

the earliest of known Conifers, belonged to the *Taxineæ*, the lowest of these coniferous types, and of which the living *Salisburia* may perhaps be regarded as the least advanced form.

Thus far our attention has been directed only to plants whose affinities have been ascertained with such a degree of probability as to make them available witnesses, so far as they go, when the question of vegetable evolution is *sub judice.* But there remain others, and probably equally important ones, respecting which we have yet much to learn. In most cases we have only met with detached portions of these plants, such as stems or reproductive structures, neither of which are we able to connect with their other organs. The minute tissues of these plants are preserved in an exquisite degree of perfection; hence we can affirm that, whatever they may be, they differ widely from every living type that we are acquainted with. The exogenous stems or branches from Oldham and Halifax which I described under the name of *Astromyelon*,[1] and of which a much fuller description will be found in my forthcoming Memoir xii., belong to a plant of this description. The remarkable conformation of its bark obviously indicates a plant of more or less aquatic habits, since it closely resembles those of *Myriophyllum*, *Marsilea*, and a number of other aquatic plants belonging to various classes. But its general features suggest nearer affinities to the latter genus than to any other. Another very characteristic stem is the *Heterangium Grievii*,[2] only found in any quantity at Burntisland, but of which we have recently obtained one or two small specimens at Halifax. This plant displays an abundant supply of primary, isolated, vascular bundles, surrounded by a very feeble development of secondary vascular tissue. Still more remarkable is the *Lyginodendron Oldhamium*,[3] a stem not uncommon at Oldham, and occasionally found at Halifax. Unlike the *Heterangium*, its primary vascular elements are feeble, but its tendency to develope secondary zylem is very characteristic of the plant. An equally peculiar feature is seen in the outermost layer of its cellular bark, which is intersected by innumerable longitudinal laminæ of prosenchymatous tissue, arranged in precisely the same way as is the hard bast in the Lime and similar trees, affording another example of the introduction into the outer bark of the *appareil de soutien.* As might have been anticipated from this addition to the bark, this plant attained arborescent dimensions, very large fragments of sandstone casts of the exterior surface of its bark[4] being very abundant in most of the leading English coal-fields. Corda also figured such a cast[5] from Radnitz, confounding it, however, with his Lepidodendroid *Sagenaria fusiformis*, with which it has no true affinity. Of the smaller plants of which we know the structure but not the systematic position, I may mention the beautiful little *Kaloxylons.*[6] We have also obtained a remarkable series of small spherical bodies, to which I have given the provisional generic name of *Sporocarpon.*[7] Their external wall is multicellular; hence they cannot be spores. Becoming filled with free cells, which display various stages of development as they advance to maturity, we may infer that they are reproductive structures. Dr. Dawson has recently supplied me with some similar bodies, also containing cells, from the Devonian beds of North and South America. Except in calling attention to some slight resemblance existing between my objects and the sporangiocarps of *Pilularia*,[8] I have formed no opinion respecting their nature. Dr. Dawson has pointed out that his specimens also are suggestive of relations with the Rhizocarpæ.

I am unwilling to close this address without making a brief reference to the bearing of our subject upon the question of evolution. Various attempts have

[1] *Memoir* ix., in which I only described decorticated specimens. Messrs. Cash and Hick described a specimen in which the peculiar bark was preserved under the name of Astromyelon Williamsonis. See *Proceedings of the Yorkshire Polytechnic Society*, vol. vii. part iv. 1881.

[2] *Memoir* iii.

[3] *Memoir* iii.

[4] *Memoir* iv. Pl. xxvii.

[5] *Flora der Vorvelt*, tab. 6, fig. 4.

[6] *Memoir* vii.

[7] *Memoirs* ix. x.

[8] *Memoir* ix. p. 348.

been made to construct a genealogical tree of the vegetable kingdom. That the Cryptogams and Gymnosperms made their appearance, and continued to flourish on this earth, long prior to the appearance of the Monocotyledonous and Dicotyledonous flowering plants, is at all events a conclusion justified by our present knowledge so far as it goes. Every one of the supposed Palms, Aroids and other Monocotyledons has now been ejected from the lists of Carboniferous plants, and the Devonian rocks are equally devoid of them. The generic relations of the Carboniferous vegetation to the higher flowering plants found in the newer strata have no light thrown upon them by these Palæozoic forms. These latter do afford us a few plausible hints respecting some of their Cryptogamic and Gymnospermous descendants, and we know that the immediate ancestors of many of them flourished during the Devonian age, but here our knowledge practically ceases. Of their still older genealogies scarcely any records have been discovered. When the registries disappeared, not only had the grandest forms of Cryptogamic life that ever lived attained their highest development, but even the more lordly Gymnosperms had become a widely diffused and flourishing race. If there is any truth in the doctrine of evolution, and especially if long periods of time were necessary for a world-wide development of lower into higher races, a terrestrial vegetation must have existed during a vast succession of epochs ere the noble Lycopods began their prolonged career. Long prior to the Carboniferous age they had not only made this beginning, but during that age they had diffused themselves over the entire earth. We find them equally in the old world and in the new. We discover them from amid the ice-clad rocks of Bear Island and Spitzbergen to Brazil and New South Wales. Unless we are prepared to concede that they were simultaneously developed at these remote centres, we must recognise the incalculable amount of time requisite to spread them thus from their birth-place, wherever that may have been, to the ends of the earth. Whatever may have been the case with the southern hemisphere, we have also clear evidence that in the northern one much of this wide distribution must have been accomplished prior to the Devonian age. What has become of this pre-Devonian flora? Some contend that the lower cellular forms of plant life were not preserved because their delicate tissues were incapable of preservation. But why should this be the case? Such plants are abundantly preserved in Tertiary strata, why not equally in Palæozoic ones? The explanation must surely be sought, not in their incapability of being preserved, but in the operation of other causes. But the Carboniferous rocks throw another impediment in the way of constructors of these genealogical trees. Whilst Carboniferous plants are found at hundreds of separate localities, widely distributed over the globe, the number of spots at which these plants are found displaying any internal structure, is extremely few. It would be difficult to enumerate a score of such spots. Yet each of those favoured localities has revealed to us forms of plant life of which the ordinary plant-bearing shales and sandstones of the same localities show no traces. It seems, therefore, that whilst there was a general resemblance in the more conspicuous forms of Carboniferous vegetation from the Arctic circle to the extremities of the southern hemisphere, each locality had special forms that flourished in it either exclusively or at least abundantly, whilst rare elsewhere. It would be easy, did time allow, to give many proofs of the truth of this statement. Our experiences at Oldham and Halifax, at Arran and Burntisland, at St. Etienne and Autun, alike tell us that such is the case. If these few spots which admit of being searched by the aid of the microscope have recently revealed so many hitherto unknown treasures, is it not fair to conclude that corresponding novelties would have been furnished by all the other plant-producing localities if these plants had been preserved in a state capable of being similarly investigated? I have no doubt about this matter; hence I conclude that there is a vast variety of Carboniferous plants of which we have as yet seen no traces, but every one of which must have played some part, however humble, in the development of the plant races of later ages. We can only hope that time will bring these now hidden witnesses into the hands of future palæontologists. Meanwhile, though far from wishing to check the construction of any legitimate hypothesis calculated to aid scientific inquiry, I would remind every too ambitious

student that there is a haste that retards rather than promotes progress; that arouses opposition rather than produces conviction, and that injures the cause of science by discrediting its advocates.

The following Papers and Reports were read:—

1. *Notes on Geological Sections within Forty Miles Radius of Southport.*[1] *By* C. E. De Rance, *F.G.S.*

The sections in Silurian works of the Lake District and North Wales within the radius are described, also those in the Carboniferous limestone, Coal Measures, the Permian and the Triassic rocks, especially the Keuper sandstones and marls around Southport. The sections in the glacial drift of West Lancashire and Cheshire are mentioned, and the sequence and character of the overlying post-glacial beds. Southport is built upon blown sand, resting on peat, which is 79 feet below the surface at the sea-coast, rising inland to the surface; the whole series rests on the Keuper marls, which have been bored into to a depth of 187 yards at the Palace Hotel, Birkdale, without finding the base. Fragments of gypsum and pseudomorphous crystals of salt occurred in the boring. The sections in the Mersey tunnel, now in course of construction, were alluded to.

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2. *Section across the Trias recently exposed by a railway excavation in Liverpool.* *By* G. H. Morton, *F.G.S.*

During the last eight years a very important section of the Triassic strata has been exposed in Liverpool by excavations for widening the line of the London and North-Western Railway Company. The section presents a solid wall of sandstone on both sides of the new railway-cutting from Lime Street Station to Edge Hill Station, a distance of 2,300 yards from east to west. The height of the rock on each side varies. The strata exposed belong to the Keuper and Bunter formations. The pebble-beds of the Bunter crop out for 914 yards along the east of the cutting, but do not contain any marl partings, and not a single pebble of any kind has been noticed. Only two faults occur along the whole length of the pebble-beds exposed, and they are of very little importance. The subdivision ends at Smithdown Lane, where there is a fault, with a downthrow to the west, which brings in the upper mottled sandstone, the highest member of the Bunter formation, where it is not represented on the map of the Geological Survey or the fault recorded. The upper mottled is a fine-grained, soft, bright red sandstone with grey streaks, and, as it readily crumbles into sand, is never hard enough for building purposes. It crops out to the west from Smithdown Lane to University College, when a fault throws down the strata about 600 feet and brings in the Keuper sandstone, which is 400 feet thick and interstratified with beds of marl. The highest beds of the Keuper are at the College; lower strata containing the beds of marl crop out from beneath, and are thrown down to the west by faults three times in succession when the basement beds crop up in Lime Street Station.

The section shows that all the faults throw down the strata to the west and bring in higher beds in that direction. It also shows the exact position of the fault between the Bunter and Keuper formations, which was not known before.

The position of the Keuper as a wedge-shaped mass of sandstone, with the Bunter formation faulted against it on the east and west, is of great local interest, and it is easy to understand how the succession of the strata has not been satisfactorily explained before, in the absence of any such a continuous section as that described.

The remarkable absence of faults in the pebble-beds has an important bearing on the construction of the Mersey tunnel, which will have to be carried through those beds along its entire length. The section shows that while faults are

[1] *Geological Magazine*, Nov. 1883.

numerous in the Keuper sandstone, which was frequently fractured during subsidence into a depression, the pebble-beds are very little faulted. A few days ago, when under the Mersey, I did not find a single fault either in the tunnel or in the heading beneath.

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3. *The Master-Divisions of the Tertiary Period.* *By* Professor W. Boyd Dawkins, *F.R.S.*

(1) Introduction.

The classification of Tertiary rocks sketched out some fifty years ago, and since then altered in no important degree, is out of harmony with our present knowledge, and the definitions of the series of events which took place in it has been greatly modified by the progress of discovery in various parts of the world. The terms Eocene, Meiocene, and Pleiocene no longer express the idea of percentages of living species of fossil mollusca upon which they were based, and 'Post-tertiary, Quaternary,' and 'Recent' are founded on the assumed existence of a great break comparable to that separating the Secondary from the Primary or Tertiary Periods, which has long ago been given up. In 1880[1] the author proposed a classification of the Tertiary Period in Europe by an appeal to the land-mammalia, and since that time his definitions have been found to apply equally well to the Tertiaries of Asia and the Americas, and to the later Tertiaries of Australia. He therefore presents the following outline to the members of the British Association.

(2) The Principle of Classification.

The forms of life in the rocks have changed at a very variable rate, and in direct proportion to their complexity of organisation, the lower and simpler having an enormous range in the rocks, while the higher and more complex have a much narrower range, and have been more easily affected by changes in the environment. The carboniferous conifers, for example, do not differ profoundly from living forms, while the carboniferous labyrinthodons have left no representatives behind them. At the beginning of the Tertiary Period the whole of the vegetable kingdom, and with but some few exceptions the invertebrata in the animal kingdom, had arrived at the stage of evolution which they now present. The fishes, amphibians, and reptiles belong to well-recognised types in existing nature, and the birds had left behind the ancestral characters which allied them so closely to the reptiles in the Secondary Period—the long tail, and the armature of teeth in their beaks—and belong to living orders.

The mammalia, on the other hand, feebly represented in the Secondary Period by small marsupial forms, appear in force in the early Tertiary beds, and were, as Prof. Gaudry happily terms it, 'en pleine évolution' in the early divisions of the Tertiary strata—the Eo-, Meio-, and Pleio-cene Ages—and have changed with sufficient swiftness to allow of their being used to mark the hour on the geological clock in different parts of the world.

(3) The Tertiary Period includes our own Time.

Nor can there be any doubt as to the definition of the series of events included under the term Tertiary. It begins with the appearance of the placental mammalia, and it must include our own time if it be looked at from the same biological point of view as the Primary or Secondary groups. With some few exceptions the whole of the plants and animals now alive were living in the Pleiocene and Pleistocene ages, and therefore there is no break of sufficient importance to justify the use of the terms 'post-Tertiary' or 'Quaternary' for the newer divisions. These exceptions are probably due merely to the accident of their non-discovery in the Pleiocene and Pleistocene strata.

[1] *Quarterly Journal of the Geological Society, London*, Aug. 1880. See also my work on *Early Man in Britain*, 1880.

(4) THE MASTER-DIVISIONS OF THE TERTIARY PERIOD.

The master-divisions of the Tertiary Period may be defined by the following characters so far as relates to the mammalia:—

a. The Eocene Age, or that in which the placental mammals now on the earth were represented by allied forms belonging to existing families and orders. No living genera of placental mammals were present either in the Old or the New World. For example, the order *Primates*, to which man belongs, is represented by lemur-like creatures (*adapis*) in the Upper Eocenes of Europe, and in the Lower Middle and Upper Eocenes of the United States. The Eocene carnivores present close affinities with the marsupials, and one living marsupial genus (*didelphys*), opossum, haunted the Eocene forests of Europe.

b. The Meiocene Age.—In the Meiocene Age we meet with living genera for the first time, such as rhinoceros, cervus, antelope, tapir, hog, cat, hyæna, and others. The Primates are represented by higher forms than before, by the simiadæ, or true apes, both in the Old and New Worlds. It is also worthy of note that in the Lower Meiocene Period in Europe marsupials were still present. The opossums still lingered in the forests, and the marsupial ancestry of the carnivores still asserted itself in the singular combination of characters offered by the *hyænodon.*

The term Oligocene, originally invented by Professor Beyrich in 1856, and recently adopted in Britain by Professor Judd, embraces the Upper Eocenes and the Lower Meiocenes. It appears to me an unnecessary subdivision and to be incapable of definition by its fossil contents from the Upper Eocene and Lower Meiocene strata. It includes such characteristic forms as the Upper Eocene *palæotherium* and the Meiocene *deinotherium.*

c. The Pleiocene Age.—In the next or Pleiocene Age the living genera are abundant, and living mammalian species appear, such as the hippopotamus, in a fauna mainly characterised by extinct species of mammalia.

d. The Pleistocene Age.—In the Pleistocene Age living species of placental mammals predominated greatly over the extinct, and cave- and river-drift man appears. In this age the mammal fauna of the whole world reached its present phase of development—in Europe the European, in India the Indian, and in North and South America the types now found in those parts of the world. In Australia also the marsupials present the same stage of development, and the living marsupials are more numerous than the extinct. The term 'Glacial,' sometimes used as the equivalent of Pleistocene, is merely of local application, and applies only to those regions in which the traces of glaciers and icebergs occur, where glaciers and icebergs are no longer to be found. 'Quaternary' is open to the grave objection mentioned above, that it implies a break in life which has no existence.

e. The Prehistoric Period.—The vegetable and animal kingdom had arrived at their present stage of specialisation at the close of the Pleistocene Age, and therefore the series of events from that age down to the present time must be looked at from a point of view other than that offered by the evolution of the mammalia. The point of view which seems to me the best is that offered by history, and they may be divided into the prehistoric and the historic. The prehistoric period is that in which the domestic animals and cultivated fruits appear. Man is abundant, and in the neolithic bronze and iron stages of culture.

f. The *Historic Period*, or that embraced by the written records, varies in different countries.

These definitions are, so far as the author knows, no mere parochial definitions applicable to a limited area, but apply to the series of events in the Tertiary Period over the whole world. They are the result of an inquiry which he undertook some twenty years ago at the request of his late friend John Richard Green, to see whether the series of events recorded in the Tertiary strata could be brought into relation with those recorded by history.

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4. *Report on the Exploration of Caves in the Carboniferous Limestone in the South of Ireland.*—See Reports, p. 132

5. *Report on the Exploration of Raygill Fissure, Yorkshire.*— See Reports, p. 133.

6. *On the Occurrence of Remains of Labyrinthodonts in the Yoredale Rocks of Wensleydale. By* JAMES W. DAVIS, *F.G.S.*

Prof. Miall has described the bones of a portion of the hind limb of a labyrinthodont in the 'Quart. Journal of the Geological Society,' vol. xxx. p. 775. They were found in a dark-coloured flag-rock above the Harmby Quarry and extending with an easterly dip to Harmby Railway-Cutting. The same flag-rock extends behind Leyburn and the Shawl, and in that locality it has been extensively quarried. In addition to the leg-bones already mentioned others have been found in the same flag-rock, but separated by considerable distances, so that it is not probable that they belonged to the same labyrinthodont. In the railway-cutting a portion of a cranium was found. It is 1·9 inch in length and 1·4 in breadth. Its thickness is ·15 of an inch and is of a somewhat open and porous structure. A longitudinal depression extends completely across the upper surface, on each side of which, and parallel with it, is a well-developed convexity. A number of sutures, not very well defined, seem to indicate that the bone occupied a position in the skull probably between and immediately behind the orbits, and extending backwards to the occipitals, comprising the frontals, parietals, part of the occipital, and a portion of the squamosal bones. The under surface is coarsely striated and porous, corresponding generally to the upper surface.

The third specimen was found in the quarries beyond the Shawl N.W. of Leyburn and exhibits casts of the jaws of a labyrinthodont. Each ramus is about 3 inches in length; they have been disturbed and displaced. The rami at a distance of 1 inch from the posterior extremity are ·5 of an inch in depth, beyond which they gradually taper to the anterior extremity. The external surface of the jaws was ornamented with a reticulated arrangement of tubercles, an impression of which is preserved in the specimen. Along the margin of the impression of the alveolar portion of one of the rami there is a series of impressions which appears to have been caused by small pointed teeth. The specimens are perhaps too fragmentary to afford sufficiently good characters on which to base determinations of specific or even generic value; and the wide dispersal of the bones, though in the same stratum, renders their affinity problematical.

7. *On some Fossil Fish-Remains found in the Upper Beds of the Yoredale Series at Leyburn, in Yorkshire. By* JAMES W. DAVIS, *F.G.S.*

The red limestone forms the upper part of the main limestone of Phillips, being separated from it by only 1 foot of shale or plate. It is about 100 feet below the millstone grits, the intermediate beds being composed of grits and shales, with one bed of limestone about 16 or 18 feet thick. A peculiar aggregation of fish-remains has been discovered in the red beds by Mr. Wm. Horne, of Leyburn. They comprise nearly forty species, the majority of which are peculiar to the beds; others, like Cladodus and Petalodus, are common to the mountain limestone, and do not appear to differ either in size or otherwise from those of the lower massive limestone. The representatives of the genera Psammodus, Cochliodus, and Polyrhizodus, which are found abundantly in the lower limestone, and are of great size and importance, are in this locality comparatively small and rare, and appear to indicate that the fishes they represent were gradually becoming extinct. Their representatives are not known to occur in the superimposed millstone grits either in this locality or in any other. There are in addition species of the genera Megalichthys and Pleurodus, which are characteristic of the coal measures. The presence of so varied a fauna naturally leads to the inference that the circumstances under which they existed were not those usually characteristic of the aggregation of limestones, but rather indicate a shallow or shore deposit with occasional influxes of

fresh water. Megalichthys and Pleurodus are fishes which in the coal measures probably lived in fresh or brackish water; and though they may have been adapted to exist in marine conditions, the occurrence of beds of sand and shale intercalated with the thin limestones of the Yoredales evidently shows the proximity of land, and it is probable that they were carried to their present position by rivers and there deposited with the marine forms with which they are associated. The supposition that the water was brackish may account for the small size of some of the genera already mentioned, and their final extinction in the grits and shales which succeed the limestone. The great fishes whose remains are found in the lower limestone, represented by Ctenacanthus, Oracanthus, and others, are absent, the only spines hereto found being those of Cladacanthus and Physonemus.

FRIDAY, SEPTEMBER 21.

The following Reports and Papers were read:—

1. *Eleventh Report on the Erratic Blocks of England, Wales, and Ireland.* See Reports, p. 136.

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2. *On some supposed Fossil Algæ from Carboniferous Rocks. By* Professor W. C. Williamson, *LL.D., F.R.S.*

During past years many objects have been figured and described by authors under various names, but all of which have been regarded by some palæontologists as Fucoids. One very curious group especially, obtained from the pre-carboniferous rocks, has been described under such names as Bilobites, Chrossochorda, &c. The Rev. Isidore Kavannah, a young alumnus of Stonyhurst College, near Whalley, about a year ago placed in the author's hands a number of specimens which he had found in Yoredale rocks on the banks of the Hodder, near the college. These specimens would be considered by those who believe in the vegetable nature of such examples to belong to the genus Chrossochorda. M. Nathorst has recently given excellent reasons for regarding all such specimens as being merely the casts of the depressed tracks of Crustaceans, worms, and other animals, and in plate 1, fig. 1 of his memoir[1] he has figured one formed by the crustacean *Corophium longicorne*, which, in its essential features, corresponds with the various Chrossochordæ. Hitherto none of these latter objects have been found in the carboniferous rocks; but since the author received the Stonyhurst specimens Mr. Robert Kidson, of Stirling, has figured one from the Carboniferous beds of Liddlesdale, under the name of *Chrossochorda carbonaria*. In his specimens the pennatiform ridges given off obliquely from the central longitudinal furrow are smooth. In the author's specimens they are markedly muricated or regularly tuberculated. Whilst wholly rejecting the idea of these objects being other than the casts of animal tracts, these specimens may be known provisionally as *Chrossochorda tuberculata*.

A number of casts strikingly representing branching algæ were made on a smooth sandbank at Llanfairfechan, in North Wales, where drainage channels left by each retiring tide resembled in a most remarkable manner some of the objects described as fossil Algæ. Specimens of these casts were exhibited.

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3. *Report on the Fossil Plants of Halifax.*—See Reports, p. 160.

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[1] *Om Spår af några evertebrerade djur M. M. Och Deras Paleontologiska Betydelse.* A. G. Nathorst. Stockholm, 1881.

4. *On the Geological Relations and Mode of Preservation of Eozoon canadense.* *By* Principal J. W. Dawson, *C.M.G., F.R.S.*

The oldest known formation in Canada is the Ottawa gneiss, or fundamental gneiss, a mass of great but unknown thickness, and of vast area, consisting entirely of orthoclase gneiss, imperfectly bedded and destitute of limestones, quartzite, or other rocks which might be supposed to indicate the presence of land-surfaces and ordinary aqueous deposition. It constitutes the lower part of the Lower Laurentian of Logan, and may be regarded either as a portion of the earth's original crust, or as a deposit thereon by aqueo-igneous agency and without any evidence of derivative deposits.

Succeeding this is a formation of very different character, though still belonging to the Lower Laurentian of Logan. It may be named the Grenville series, and includes beds of limestone, quartzite, iron ore, and graphitic and hornblendic schists, with evidence locally of pebble-beds. It is in this, and especially in one of its great limestones, the Grenville limestone, that *Eozoon canadense* occurs. It was shown that these limestones are regularly bedded and of great horizontal extent. The Grenville formation presents lithological evidence of ordinary atmospheric erosion of the older rocks and of ordinary aqueous as well as organic deposition.

Above this is the Norian series, or Upper Laurentian of Logan, in which lime felspars become dominant, and show that the calcareous rocks accumulated in the preceding period were already contributing to the material of new deposits. No evidence of Eozoon has been found in this formation, which is thus far entirely unfossiliferous.

The Huronian and other series, also eozoic or pre-Cambrian rocks, overlie the Norian, and in one of these, the Hastings group, belonging probably to the Taconian of Hunt, specimens of Eozoon and indications of worm-burrows and other obscure fossils have been found.

With reference to the mode of preservation of Eozoon, it was stated that in its ordinary condition, as mineralised by Serpentine, it presents the simplest kind of mineralisation of a calcareous fossil, that in which the original calcite walls still exist, with no change except a crystallisation of the calcite common in the fossils of newer formations, and with the cavities filled with a hydrous silicate which was evidently in process of deposition on the sea-bottom on which Eozoon is supposed to have lived. Commencing with this fact, the author proceeded to show that the various imperfections and accidents of preservation observed in Eozoon are precisely parallel to those observed in palæozoic and mesozoic fossils.

In conclusion it was stated that many new observations had been made by Dr. Carpenter and the author, and would appear in a memoir now in course of preparation by the former; and that the author hoped, on occasion of the visit of the British Association to Canada next year, to exhibit to those interested in the subject the large series of specimens now in the museum of McGill University.

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5. *On the Geological Age of the North Atlantic Ocean.* *By* Professor Edward Hull, *LL.D., F.R.S.*

In this paper the author made use of three leading formations, as factors in his inquiry, viz., the Archæan (or Laurentian), the Silurian (chiefly the Lower Silurian), and the Carboniferous.

(1) Dealing with the Archæan, he traced its range both through the North American continent, and that of Europe and the British Isles, showing that there is every reason for concluding that the strata of this age underlie all the more recent formations of these tracts, and assuming that the metamorphic beds (consisting of granite or gneiss, hornblendic and other schists, quartzites, &c., of pre-cambrian age), were originally oceanic sediments, he drew the inference that the originating lands of these sediments were situated in the region intermediate between North America and Europe, in other words, in the Central and North Atlantic region, probably including Greenland.

(2) As regards the Silurian (Lower Silurian rocks), he showed by comparison of sections over the North American continent (*a*) that the strata referable to this epoch swell out as they approach the eastern seaboard, and thin away, or pass into calcareous beds in the opposite direction. Similarly it was shown that the sediments of this epoch in Europe swell out westwards, and thin away, or pass into calcareous strata in an opposite direction, as shown by a comparison of the sections in the British Isles, the north-west of France, and north of Spain, with those of Russia. Thus, while the Lower Silurian beds of Britain and the north of France have a thickness of from 20,000 to 25,000 feet, in which beds of limestone are exceptional, those of the Baltic provinces and the shores of the Gulf of Finland have dwindled down to a thickness of only 1,500 feet, of which limestones, as shown by Professor Schmidt, form an important portion.

From the above comparisons the conclusion was drawn that when the Lower Silurian beds were being formed, the originating lands must have lain over the area of the Atlantic Ocean, that being the region towards which the strata swell out on either hand; while the replacement of the sediments by limestone indicates the position of the contemporaneous oceans over Central Europe and Western America.

(3). In a similar manner, dealing with the Carboniferous strata, the author showed by a comparison of sections, that over the American area the sedimentary strata swell out in the direction of the Atlantic shore, while they thin down or pass into limestones in the direction of the Rocky Mountains; so that (with one notable exception, that of the Weber quartzite in Nevada) both the upper and lower Carboniferous beds consist mainly of marine limestones in the western States, while their representatives of North-East America swell out into about 15,000 feet of strata, consisting throughout of sedimentary materials.

Reverting to the British Isles, the author referred to former papers in which he had shown how the sedimentary materials of the Carboniferous period swell out both towards the N.W. and S.W. of the British Isles, while the calcareous beds thin out or are replaced in the same directions.

From these and other considerations the author had long since inferred the position of the originating lands to have been to the north-west and south-west of the British area; and connecting this with the evidence afforded by the Carboniferous sediments of America, he concluded that it was one and the same Atlantic continent which had given forth the materials of which the Carboniferous series on either hand had been constructed.

Thus it would appear that throughout the Archæan, or Laurentian, the Lower Silurian, and the Carboniferous epochs, the regions of North America on the one hand, and of the British Isles and Western Europe were submerged, while a large part of the North Atlantic area existed as dry land, from the waste of which these great formations had been built up: and he urged that if such were the case, the doctrine of the permanency of oceans and continents, as tested by the case of the North Atlantic, falls to the ground.

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6. *On the Influence of Barometric Pressure on the Discharge of Water from Springs. By* Baldwin Latham, *M.Inst.C.E., F.G.S., F.R.M.S.*

In 1881, at the York meeting of the British Association, the author gave the result of a series of observations which he had carried on with reference to the influence of barometric pressure on the discharge of water from the ground, and he showed from the result of a series of gaugings of the periodical bourne-flow at Croydon, that there were certain times when the underground waters were influenced by barometric pressure, and that with a fall of the barometer an increase in the quantity of water discharged from the springs occurred. The fluctuation due to barometric pressure in the case of the Croydon bourne-flow at one period had exceeded half a million gallons per day. It was also shown from the results of percolating gauges, that even in a period of extreme dryness, with a rapid fall of the barometer, a small quantity of water passed out of the percolating gauges.

Since the foregoing observations were made, the author has had an opportunity

of continuing his observations, and finds that percolating gauges are affected in the same way under the influence of barometric pressure as shown on a former occasion; but in order to make a crucial test as to whether or not the water flowing from an artesian well would be affected by variations of barometric pressure, he instituted a series of observations at the end of the year 1881 and the beginning of 1882, in connection with a well which he had had bored at the Croydon Rural Sanitary Authority's works in the lower part of Mitcham parish.

The well referred to has been bored through the London clay and Tertiary beds into the chalk, and a watertight bore-pipe inserted from top to bottom; having a steel shoe at the bottom it has been securely driven into the chalk, and the water overflows the surface. In making the experiments a length of iron pipe was fixed on the bore-pipe so as to bring it some feet above the ground level, and in the side of this pipe a small aperture was made in order to allow the overflowing water to escape, the result being that the water was headed up above the aperture about 2 feet. A float fitted with graduated rod was floated on the water in the bore-pipe, and from the observations made in this way it was found that whenever there was a fall in the barometer the column of water in the bore-pipe increased in altitude; while, on the other hand, for every rise in the barometer there was a corresponding fall in the column of water in the bore-pipe.

The results of the observations are shown upon a diagram, and establish the fact, already very clearly demonstrated with reference to the gaugings of the bourne-flow at Croydon, that barometric pressure does exercise a considerable influence in accelerating or retarding the escape of water from the ground, the cause of which the author attributes, as on a former occasion, to the expansion and condensation of the air and gases held by the water, which at a period of low barometric pressure have a tendency to escape and so facilitate the flow of water, while under the conditions of high barometric pressure the tendency is in the opposite direction, and retards the flow of the water.

SATURDAY, SEPTEMBER 22.

The following Papers and Report were read:—

1. *Some additional notes on Anthracosaurus Edgei (Baily sp.), a large Sauro-Batrachian from the Lower Coal Measures, Jarrow Colliery, near Castlecomer, County Kilkenny. By* WILLIAM HELLIER BAILY, *F.L.S., F.G.S., M.R.I.A.*

At the meeting of the British Association held at Dublin in 1878 a 'Notice of some additional Labyrinthodont Amphibia and Fish from Jarrow Colliery, County Kilkenny,' was read by the author. In this communication he alluded to a large batrachian he had previously described, and named *Anthracosaurus Edgei*, in a paper read before the Royal Irish Academy, January 13, 1873. He then estimated from the remains of that fossil, as then known, that it indicated an animal of from eight to ten feet in length.

Since that time, and during the present year, through the kindness of Joseph Dobbs, Esq., J.P., proprietor of the colliery, who has most liberally aided the author in these investigations, he has been enabled to obtain, in addition to most interesting fish-remains, for the collection of the Geological Survey of Ireland, a more complete example of this, perhaps the largest sauro-batrachian extant.

The drawing illustrating this communication exhibited as exact a representation as could be taken of this remarkable fossil, of the natural size. It shows the impression of a somewhat triangularly shaped head, viewed from the inferior or palatal surface. It measures twelve inches in length and ten inches in breadth.

The vertebral column, as preserved, numbers about sixty separate elements,

those nearest the head and belonging to the abdominal region being merely indicated; towards the extremity, however, they clearly show the attached superior and inferior spinous processes; the chain of vertebræ curves towards the tail, which is deficient.

Sixteen ribs may be counted on each side of the vertebral column, the greatest breadth of this, the abdominal portion, being ten inches.

About four and a half feet from the snout is shown the greater portion of one of the hind limbs, the femur, tibia and fibula, somewhat displaced, tarsal bones, and the first bones of the five digits.

Evidence of the dermal armour is also exhibited on this fossil, as impressions of elongated osseous scutes arranged in oblique rows.

This specimen as preserved measures nearly eight feet in length, and would have been ten or more feet to the extremity of the tail. It is impressed upon the smooth surface of a bed of impure coal, the slab containing it weighing several cwt., and its preservation reflects great credit upon the bailiff, Mr. John Bradley, who took the greatest care of it, considering the friable character of its matrix.

Another fossil obtained from this colliery at the same time, is a head, which the author believes to be also identical with *Anthracosaurus Edgei;* it is in a better state of preservation, although squeezed quite flat; it presents a profile view, and appears to be closely allied to a well-preserved head from the Shropshire coal-field in the collection of G. Maw, Esq., F.G.S., originally described as *Loxomma,* but which the author believes Prof. Huxley afterwards referred to his genus *Anthracosaurus.*

A rough drawing of the natural size of this head (from the cast in plaster) was exhibited to compare with the specimen from Jarrow Colliery, Kilkenny, which is much larger, the Dudley head measuring 13 inches in length, whilst the other is $15\frac{3}{4}$ inches long.

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2. *On Basalt apparently overlying Post-Glacial Beds, Co. Antrim.* *By* W. J. Knowles.

The author drew attention to a mass of basalt about 50 feet long, 20 feet wide, and 3 to 9 feet in thickness resting on a portion of what is known as Interglacial beds near Cullybackey, County Antrim. This is only a portion of a larger mass, a part having been removed a few years ago for road-making.

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3. *Recent Opinions on the Loess Deposits of the Valley of the Rhine.* *By* Mark Stirrup, *F.G.S.*

Mr. Stirrup criticised adversely some recent opinions of Mr. H. H. Howorth, F.S.A., which have been published in the 'Geological Magazine,' wherein Mr. Howorth has attempted to prove a 'great post-Glacial flood' by the evidence afforded by the mammoth and that of several post-Glacial or drift deposits. Mr. Stirrup pointed out that several facts connected with the loess of the Rhine valley were not consistent with the interpretation given to them by Mr. Howorth, nor was the assumption that the materials of the loess were derived from volcanic muds borne out by the evidence.

From the cumulative evidence of the palæontological and geological data Mr. Howorth infers a great diluvial movement over the larger part of the northern hemisphere, which was accompanied by an equally sudden and violent change of climate.

Mr. Stirrup maintained that the proofs advanced in support of this deluge were inconclusive and fallacious; for if the extinction of the mammoth were due to such a cataclysm, how are we to account for the survival of the reindeer, musk ox, lemming, and other animals whose fossil bones are found with those of the mammoth and whose descendants still inhabit Northern Europe?

It would have been impossible for any terrestrial animal to have survived a deluge of the character and magnitude postulated by Mr. Howorth. This attempt to resuscitate some of the obsolete doctrines of Cuvier and Buckland (whose

speculative reasoning is not in accordance with what we know of the actual operations of nature) Mr. Stirrup thought would be a retrograde movement in the history of geology, and that it would be safer to adhere to those sound principles of the Huttonian philosophy which considered the little causes, long continued, as competent to bring about the greatest changes of the earth.

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4. *On the former Physical Condition of Glendale, Northumberland. By* G. P. HUGHES.

The author exhibited horns of *Bos primigenius* (urus) and antlers of the red deer, both found fifty years since in a bog at Middleton Hall, south of Wooler. The latter has twenty-three points, and is believed to be the largest in Great Britain. They were found fourteen feet from the surface in marl, underlying peat. The bog in which they were found will now be explored, in hopes of finding more remains. The author believes that this and similar deposits elsewhere found along the valley indicate that Glendale was once a lake.

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5. *On a Conglomerate with Boulders in the Laurentian Rocks of North Uist, Scotland. By* JAMES THOMSON.

The author described pebbles and boulders, up to 5 ft. 10 in. in diameter, unstratified with the gneiss and granitoid gneiss of Harris and of Loch Maddy, in North Uist. The included fragments are of hornblendic, gneissic, and granitoid rocks. The author believes these to belong to the Laurentian series and not to a later division of the pre-Cambrian rocks.

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6. *On a Coral Atoll on the Shore-line at Arbigland, near Dumfries, Scotland. By* JAMES THOMSON.

The author briefly described the stratified rocks of the shore-line in the neighbourhood of Arbigland, and stated that a portion of these stratified rocks consisted of linear coral reefs extending for two miles along the coast line. In Arbigland bay the reefs are more or less circular in outline, recurving at either extremity. These are overlain by a series of reefs which are circular in outline, in which he found several species of the fasciculate varieties of Lithostrotion; also Syringopora, Aulopora, Cladoconus, and Monticulopora. And in the dark calcareous shale in the interior of the encircling reefs are numerous species of the Astræi-formed varieties of Lithostrotion, in dense formed masses varying in size from 1 in. to 11 ft. 10 in. in diameter. He also discovered embedded in the shale a species of fossil sponge, which has been described by Mr. Carter as *Pulvulus Thomsoni*. One specimen of this sponge measured 11 in. long by 5 in. broad. These facts imply conditions similar to those described by Dana, and Darwin in the Atolls of the present day. The Atoll at Arbigland is the first one recorded of Carboniferous age. A detailed description, with a list of fossil remains, will be published at no distant date.

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7. *Fourth Report on the British Fossil Polyzoa.* See Reports, p. 161.

MONDAY, SEPTEMBER 24.

The following Reports and Papers were read:—

1. *Ninth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to Various Towns and Districts from these Formations.*—See Reports, p. 147.

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2. *Report on the Earthquake Phenomena of Japan.*—See Reports, p. 211.

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3. *Preliminary Notice of the Earthquake of* 1881 *in the Island of Ischia.* *By* H. J. Johnston-Lavis, *F.G.S.*

The earthquake of March 4, 1881, occurred at 1.5 P.M., and resulted in the entire destruction of the greater part of Casamenella, severely injuring the upper parts of Casamicciola and Lacco-Ameno, besides Casamonte, Penella, and Fango. Beyond this extended an area, including a little of Porto d' Ischia, Faiano, Fontana, Monterone di Forio and most of Lacco, in which the houses were fissured. It will thus be seen that the area affected by the shock was a remarkably small one. The buildings of Casamenella which were in the mesoseismal area were characterised by the collapse of the roofs and floors with comparatively little injury to the walls, showing their nearness to the seismic vertical. Passing outwards in a radial manner from the seismic vertical, we find the angle of emergence rapidly declines, and the damage of the houses similarly diminishes, so that within a very short distance the effects are hardly visible.

We may therefore conclude from these facts that we have a slight earthquake having its origin very near the surface, and that its destructiveness was dependent on the same cause, for had it been at any considerable depth it might have produced movements of very slight intensity. It must also be mentioned that the peculiar style of architecture, the bad materials and workmanship, combined with age of most of the buildings, helped very greatly towards the ruin.

It will be seen that the isoseismals assume ellipsoidal figures, with their major axis running nearly east and west, and are, therefore, no doubt, derived from a fissure whose plane strikes from a few degrees east of south to a few degrees west of north, passing just west of Casamenella, and therefore forming the minor axis of the ellipsoid. It will be observed that this is not quite correct, and that the isoseismals are nearer the seismic vertical on the eastern side; this, therefore, would incline us to believe that the fissure dips slightly to the west, so that the earth-waves on the east are directed beneath and away from the surface, so as to be absorbed and lost, whilst those on the west would be directed towards the surface.

Another important point is that the isoseismals are nearer each other on the northern side; this might be explained by the axis of greatest violence exercised during the production and injection of the fissure not being perpendicular but inclined to a few degrees east of south.

Ischia, as is well known, is an old submarine volcanic cone surmounted by a large crater denuded away on the southern side. Since its upheaval at successive periods from beneath the sea, it has given birth to a number of subaërial eruptions from lateral or parasitic craterets, of which Rotaro, Montagnone, Cremate of 1302, Crater of Molara, Grotta della Terra, Casapolita, and Zale, are the principal examples. Some of these have appeared in historic times, and were preceded by a series of violent earthquakes that from time to time drove away the inhabitants.

The town of Fontana occupies the centre of the great or mother crater of Monte Epomeo, and if we draw a radial line from that village to the Marina at Lacco, we shall find that the strike of the fissure causing the earthquake lies on this line. Now it is well known that most lateral eruptions take place from a

radial fissure extending outwards from the chimney of the volcano, so that we see the position and plane of this fissure shows it to be no exception to the rule. The centre of violence on the surface occupies the same relation to the axis of the volcano as does Monte Rotaro, Montagnone, and Cremate, the three most normally placed centres of eruption, so that an outburst at this point would have just the position from which we should expect it to occur.

In the case of an active volcano, the radial fissure extends outwards from the whole length of the chimney, as pointed out by Mallet; but when we have to deal with a case similar to Ischia, the canal has no doubt been plugged by a mass of trachyte that for at least some thousands of years has been able to gradually cool from the surface downwards. Any escape, therefore, of unconsolidated igneous matter would probably occur at the point of least resistance, and so would be into the fragmentary material, in preference to following the plugged chimney. The fissure would, therefore, have a tendency to branch out, forming an angle with the main axis and extending itself by spasmodic ruptures, followed by immediate injection of igneous matter, and would not send the maximum impulse in an upward direction perpendicular to the horizon, but inclined, just as we see denoted by the eccentricity of the different isoseismal ellipsoids.

There is yet another point to be cleared up. Fontana is not included in the isoseismals, yet it suffered rather severely. Very few of the walls of the houses were damaged, but hardly a roof, of the arch masonry type especially, escaped being fissured and cracked in such a way that the fractures usually assumed a circular form in the centre of the vault, with others radially extending outwards. The wooden beams over the doors and windows were bent down or broken by a piece of masonry of a Λ shape, included in fractures extending from each upper corner of the opening in the wall. There was also no evidence of lateral movement by injuries. The people remarked a strong subsultory shock, followed by a slight undulatory one.

There is, therefore, plenty of evidence to show that we have here a series of injuries depending upon a wave issuing from the earth vertically or nearly so. How can we explain this?

We have in one earthquake two seismic verticals, one surrounded by a district in which the damage diminishes more or less gradually as we recede from the mesoseismal area; in the other we have a small mesoseismal (?) area surrounded by districts quite uninjured.

The following explanation has appeared to the author to clear up the difficulty, and therefore perhaps he may be permitted to give it.

As already stated, Fontana occupies the centre of the great crater of Epomeo, and therefore lies immediately over the old chimney, which in all probability is filled by an old plug of consolidated trachyte which must descend to the igneous reservoir. Any increase of tension in the general mass of igneous matter that might determine the further rupture of a collateral fissure would result in the conduction of any changes of pressure or vibrations along the column of highly elastic trachyte, whilst the same earth-waves would be annulled or absorbed by the inelastic tufas surrounding it, so that the blow would be struck perpendicularly to the surface and in a small area, with well-defined borders. The undulatory sensations after the principal local shock were those that were derived from the great centre of impulse beneath Casamenella.

The earthquake occurred at an epoch of general seismic activity throughout Europe, although its own vibrations were only communicated to short distances. It was felt at Vivara, Procida, Bacoli, and Misenum, and at Ventotene and Ponza very slightly. At Naples and Vesuvius, even the most delicate seismographs were undisturbed. This is comprehensible when we think over the geology of the district, and remember its composition of tufas of different but always low elasticity inclined at every imaginable angle, so that the earth-wave would be refracted and reflected every few yards, besides being absorbed by the inelastic medium.

But, moreover, it is possible to show that the earth-wave in passing from the focus to the instruments in a straight line would have to be transferred from the earth to the sea, thence to the air, thence again to the earth, or directly to the

instruments, as these are placed similarly to the towns on mountains, where the earth-wave passes beneath them, as illustrated by Mallet.

Dr. Samuel Haughton has calculated from projected objects the molecular velocity, which turns out to be 4·64 feet per second. The maximum molecular velocity was determined in three cases, and found to be 4·087, 4·553, and 5·273 feet per second respectively; the mean of all being 4·64 feet per second.

The velocity of transmission could not be obtained, partly on account of the small distances within which clocks were stopped, and the imperfect time kept.

The number of deaths resulting from this earthquake were 127.

It is said there were changes in the temperature of the mineral waters and fumaroli, but the author was unable to verify if such had really been the case, and when he examined thermometrically the principal ones, some days after, he could not find any important variations from their usual state.

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4. *Preliminary Notice on the Earthquake of July* 1883 *in the Island of Ischia. By* H. J. Johnston-Lavis, *F.G.S.*

On July 28, 1883, at 9.25 P.M., a violent shock of earthquake reduced to ruins Casamicciola, including the districts of Tresta, Olivieri, Panella, Casamonte, Mezzavia, most of Lacco, Fango, Monterone and Vajola di Forio; injuring very severely the rest of Lacco, Monticchio, the greater part of Forio, Panza, Serrara-Fontana, Fontana, Maropano, Barano, Piejo, Faiano, and Rotaro.

Beyond this extends a third area, covering most of the island, in which the houses were only slightly fissured.

The isoseismals have almost exactly the same form and arrangements as in the earthquake of 1881, but from the far greater violence of the shock, they are naturally larger. The houses included within the mesoseismal area—that is, Casamenella and the Purgatorio district of Casamicciola, with part of Fango—were ruined to such an extent that hardly the stumps of the walls were left, and it was rare to find a piece of masonry which was not reduced into its ultimate fragments, so that it was uncommon to find two or three stones still attached together. Objects were projected considerable distances, the iron tie-bars put into walls after the 1881 injuries were broken and bent like thin iron wire.

One fact very remarkable in this last earthquake was the effect of geological structure. Thus, for instance, all the houses situated on the brink of a valley where the tufa was loose and incoherent, were in most cases quite destroyed from the fissures of an incipient or complete landslip. Buildings with foundations on the loose alluvial tufas of the plains of valley bottoms have suffered much less than others built directly upon the solid tufa. We may compare, for instance, Casamonte and some farm-houses on the little plain close at hand. The most remarkable effects of this kind are the Marinas of Casamicciola and Lacco-Ameno, where some houses, that are built entirely on loose sea-sand, have only nominally suffered, whereas houses built on the tufa, and only a few paces distant, are more or less ruined. Faiano, which is almost in contact with the large masses of trachyte of Monte Toppo and Monte Vetta, has suffered very severely, probably as the result of the different vibratory increments of two materials differing so widely in their elasticity. It is no doubt due to the rapid annulling by absorption, refraction, and reflection from the media traversed, that all volcanic earthquakes are so very limited in their extension.

Besides the actual damage done to the houses, a number of landslips occurred, three of which are worthy of remark for their extension. A large one detached itself from the side of Monte Rotaro, overhanging a part of the Vallone Ombrasco. Two others started near the summit of Monte Nuovo (of Ischia) and swept down its north-eastern and north-western flanks, destroying a large tract of vine-gardens. In the former case the landslip occurred through the loose fragmentary *ejectamenta* of Monte Rotaro, whereas in the other two cases the materials were the much altered Epomeo tufas, that have been for centuries exposed to the destructive fumarolic action. This latter gave rise to some extraordinary exaggerations, such

as enormous fissures opening, from which large volumes of vapour were issuing, and similar statements. The fissures were such as exist along the edge of all landslips, and the vapour which escaped, *for only a few hours after*, was nothing more than due to the sudden exposure of a large surface of hot and moist muddy tufa, which formed the fumarole walls. The author visited with diligence, guided by the informers, the different localities where these natural wonders were to be seen, to be repaid by useless climbs beneath a broiling August sun. As he knew the island of Ischia step by step before the last catastrophe, so far as his observations go, he could find no change either in the level of any locality, or in the fumaroles or mineral waters.

It may be remarked that this is said in the face of many statements to the contrary, to the effect that some of the thermal waters boiled, or rushed out in great quantity. Now there are many persons thoroughly worthy of belief who assert such to have been the case; but there are others quite as worthy of belief who deny it. Amongst some assertions, one was that the wells dried up; but in two cases at least the *wells* turned out to be underground *cisterns* for rain water, so that how the earthquake dried up these, other than by fracturing them, the author cannot conceive.

Hardly any cliff edge but either slipped away or was fissured parallel to its borders; roads that ran along a declivity had either slipped down bodily into the valley, or were divided by fissures parallel to their axis.

One fact, however, of which there can exist not the slightest doubt, is possibly an important discovery made by Dr. Eisig, trained to scientific observation, and Mr. Petersen, the vice-director and engineer respectively of the zoological station at Naples. These gentlemen, when on a dredging excursion, with the aquarium yacht, a short time after the earthquake, noticed on the north of the island (*i.e.* opposite Casamicciola and Lacco) a number of pieces of fresh-looking pumice floating on the water. The conclusion was that there had been a submarine eruption. Thus would be explained the sensation of a blow struck at the two steamers at anchor in the roads at the moment of the shock, besides that against a boat three miles from the Punta Imperatore.

Against such supposition there are many facts. (1) No one saw the eruption. (2) Supposing it to have passed unobserved in the night, surely the next morning there would still have been some very considerable escape of eruptive materials, especially when we remember the small depth between the island and the mainland. (3) We should expect a larger amount of pumice than was really found. (4) It is hardly compatible that a mesoseismal area occurred within the island, whilst an eruption occurred a small distance away, unless this were on the continuation of the fissure, and therefore opposite Lacco. (5) The presence of floating pumice might be explained by the landslips of loose tufa, containing that material, that forms the sea cliffs in the immediate neighbourhood, and out of which it may have floated.

It is, however, to be hoped that, as the zoological station possesses dredges and diving apparatus, they will divert their attention for a day or two to the investigation of an important phenomenon, if such really exists.

Fontana, as on the occasion of March 4, 1881, again showed a set of injuries dependent on a vertical shock. This time, however, the damage was much more strongly marked, and many houses were rendered quite uninhabitable, besides some that fell. In addition to the vertical injuries were a set of fractures denoting a wave-path, coming from the north at a very low angle of emergence. The explanation proposed for the peculiarity of the injuries in this locality for 1881, seems to be confirmed; the vertical seems to be due, as then, to the conduction along a column of trachyte followed by the direct shock from Casamenella, which produced the second set of fissures. An additional confirmation of this is, that at the convent of St. Nicola hardly any signs of vertical movement are evident, whilst objects on the altar gave a distinct north and south azimuth.

The author examined the whole of the coast of the island, but could find no apparent change of level. A rough examination of the azimuths proves them to be very regular except near the mass of trachyte of Zale, which seems to have reflected the shock, so that the buildings in the neighbourhood of it, and especially on its

southern side, have received a direct and reflected wave-path, and therefore have two sets of fissures, causing much complication. The author observed a similar effect, but much less marked, in 1881.

The focus seems to have been an enlargement of the former one, and occupies, he believes, almost the same topographical position, except that its northern extremity is more prolonged. An important fact about the position of this fissure is that it nearly corresponds at its southern end with the active fumarolic area of Monte Cito, and at its northern with some altered tufas, the result of fumarolic action on the beach at Lacco, and therefore is probably along an old fracture, for, at Monte Cito, alum was collected in the fourteenth or fifteenth century.

SKETCH MAP OF THE ISLAND OF ISCHIA.

Scale 1 to 120,000. Showing isoseismals of 1881 and 1883, and fissures of each earthquake (width of fissures exaggerated).

- - - - - - -	March 4, 1881.	1. Area of maximum and total destruction.
—·—·—·—·—	July 28, 1883.	2. Area of nearly complete destruction.
		3. Area of severe injury.

Ancient craters of eruption.

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5. *Dyas* versus *Permian*. *By the* Rev. A. Irving, *B.A.*, *B.Sc.*, *F.G.S.*

This subject is brought forward for discussion both as having a special local interest, and on account of the international importance of the subject in view of the Berlin Congress next year, and the progress of the Geological Map of Europe. The author, referring to previous papers in the 'Geological Magazine' during the year 1882, in which strong reasons were given for abandoning the threefold division of the so-called Permian System, and to the discussions raised in the same periodical, maintains that the 'Permian System' of Murchison, which represents the group of strata as marked by three stages, is inapplicable to the English rocks of Post-

carboniferous age. This conclusion does not invalidate the correctness of Murchison's classification for the strata of the Permian region proper; though it must be borne in mind that during last year Mr. Twelvetrees showed, both in the 'Geological Magazine' and in a paper read before the Geological Society, that further south, in the Orenburg country, a true Dyassic facies, as it is understood in Germany, can be recognised; the Rothliegende (with some subordinated limestones, as in Germany) being succeeded upwards by a true Zechstein formation, the latter being overlain conformably by a series of cupriferous marls and sandstones ('Upper Permian' of Murchison). The data given by Mr. Twelvetrees are all in favour of the view which regards these marls and sandstones as a transition series between the Dyas and Trias, which very nearly coincides with the views expressed by M. Jules Marcou at the time when Murchison's 'Permian System' was first propounded. Reference is also made to the transition series of Gümbel, which occurs in Southern Tyrol, described by the author in a paper on the *Triassic Deposits of the Alps* in the 'Geological Magazine,' November 1882, and in his Report to the British Committee of the International Geological Commission. In both of these papers the general equivalence of the English Post-carboniferous and the German Dyas is pointed out, reasons for such a conclusion having been given in the earlier papers more at length. The term 'Permian' has therefore only a local and subordinate value, and scarcely applies even to the whole Russian area in which these strata are developed.

This summer the author has spent some time at work upon the German and Austrian series of Post-carboniferous rocks, and has had the able assistance of Dr. Von Hauer, Professor Geinitz, Professor Liebe, and others. The main purpose of the present communication is to bring forward new facts bearing upon the relation of the Dyas and Trias of Central Europe. These facts have been gleaned (1) from a study of the collections of the *Geologische Reichsanstalt* of Vienna; (2) from a recent communication to the *Isis* in Dresden by Professor Geinitz, containing a description by Hr. A. Dittmarsch of the extensive erosion of the Upper Zechstein (Plattendolomit) at Ostrau, in Silesia; (3) from a series of quarries near Meerane in Saxony, which the author (at the suggestion of Professor Geinitz) has lately visited, and in which the unconformity of the lowest Bunter strata (Murchison's 'Bunterschiefer') with the Zechstein is most pronounced and unmistakable (sections were described); (4) from a week's work in Northern Thüringen, where, both in detail and on a larger scale, the break in the stratigraphical sequence of the Dyas and Trias is shown to be absolute and complete. The German terminology (*Dyas* and *Trias*), which was first established on a consideration of their organic remains, is thus fully confirmed by physical and stratigraphical evidence, and the idea of a conformable sequence of the Bunter upon the Zechstein, which has been so strongly insisted upon by Murchison and his *collaborateurs*, is shown to be a fiction. From which it follows that the application of the 'Permian System,' as propounded by Murchison, to the Post-carboniferous rocks of Central Europe is no longer tenable, any more than is its application to the British series, as the author has shown elsewhere.

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6. *On the Coloration of some Sands, and the Cementation of Siliceous Sandstones. By the* Rev. A. Irving, *B.A.*, *B.Sc.*, *F.G.S.*

In the first part of this paper attention is drawn to the occurrence of certain green-coloured sands which are frequently met with below the peaty layers, at the heads of the small valleys, in the Upper Bagshot sands. The local and exceptional nature of these green deposits, and their relation to the decomposing vegetal matter which has overlain them for a long period of time, suggest the connection of the green colour with the decomposition of vegetation. Chemical analysis of these sands shows that the green colour is in no way connected with any of the ordinary green minerals which enter into the formation of rocks, but reveals the *organic* origin of the colouring matter. For details of this, reference is made to papers by the author, one read before the Geologists' Association, the other in the

'Geological Magazine,' in which the matter is treated at length. The green sands are simply *dirty* quartz-sand, with more or less of fine clayey material. By boiling in concentrated sulphuric acid the colour is quite destroyed, and the acid blackened: long boiling in caustic potash also removes the green colouring matter for the most part, but leaves some grains coated with a black amorphous substance, which the author considers to be *humic* acid, perhaps in combination with the silica. Both the black and the green materials, which appear only as incrustations of the grains under the microscope, often cementing smaller grains to the larger ones, can be removed by chemical reagents, and microscopic examination then shows a pure sand, made up partly of rounded, partly of angular grains, and exhibiting no trace of colour beyond a thin translucent pellicle of peroxide of iron after treatment with potash. Not a single grain of any green mineral has been found by the author in the green sands of either the valley-heads, or of the Middle and Lower Bagshot series, which both chemical and microscopic examination prove to owe the green, olive-green, and black coloration of their grains to amorphous matter of vegetable origin. Crenic and apocrenic acids are precipitated from the alkaline solutions in which these sands have been boiled, as well as from the waters of deep wells which are supplied from the Middle and Lower Bagshot strata where the green sands predominate; and the proportion of crenic acid increases with the increase of the depth of shade of the green colour of the sand as a whole. The paper on the action of humus acids by A. A. Julien (Am. Ass. Sci., 1879) is referred to, as confirming generally the author's conclusions on this part of the subject. The author has extended his observations to certain other sands, and shown that in them too the colouring matter is largely due to the influence of these vegetal acids. These include the grey sandstones of the Molasse, near Lucerne, the green marls of the Upper Keuper, and a bed of dark green sand in the Woolwich and Reading beds near Croydon. Evidence is also given of the part they seem to have played in the 'mottling' of certain sandstones, and the *contemporaneous* coloration of the red sandstones generally, by the formation of soluble ferrous salts, from which the peroxide of iron was afterwards precipitated by atmospheric oxidation in shallow waters. To their action is also attributed the bleaching out of iron from the surface sands, and its subsequent deposition at no great depth, to form the cementing material of the 'pan' which is so frequently met with below the superficial layer of sandy districts in the Bagshot country, in Scotland, in America, and elsewhere.

In the second part of the paper attention is drawn to some recent investigations by the author, of the origin of the siliceous cementing material of the sarsen-stones, which occur in the newest Bagshot strata and in the sandy strata of the Woolwich and Reading beds of the London basin. Reference is made to a fuller statement of the author's views in the paper before referred to. Looking to the facts (1) that (as the author has demonstrated) silica can be replaced and precipitated in the hydrated condition from soluble alkaline silicates by saturating their solutions with CO_2; (2) that from such a gelatinous hydrate of silica, a glassy variety of silica separates out on removal of the water of hydration; (3) that microscopic examination of thin sections of sarsen-stones shows them to be composed of clear quartz-grains enclosed in a glassy siliceous matrix; (4) that felspars (as is well known) are decomposed by CO_2 with deposit of kaolin; (5) that kaolin is abundantly present in the siliceous matrix in which the quartz-grains are included —the author regards the induration of these sarsen-stones, and perhaps of siliceous sandstones and grits generally, as due to the accidental presence of felspar in the sand as it was originally deposited, and to the decomposition of this, with simultaneous liberation of silica and kaolin by carbon dioxide, and by the still stronger humus acids, which must have been copiously supplied by decomposing vegetation.

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7. *On a Boulder from the Chloritic Marl of Ashwell, Herts.* *By* H. George Fordham, *F.G.S.*

The boulders which are occasionally found in the Chloritic Marl in the workings for the so-called coprolites in Cambridgeshire and the neighbouring counties are

usually little more than pebbles. In the descriptive list of the more important of these boulders and pebbles given in a paper read before the Geological Society, in November 1872, by Messrs. W. J. Sollas and A. J. Jukes-Browne ('On the Included Rock-fragments of the Cambridge Upper Greensand,' *Quarterly Journal of the Geological Society*, vol. xxix. p. 11), the largest specimen mentioned has the dimensions $14 \times 12 \times 6$ inches.

The boulder now noted measures $12 \times 9\frac{1}{2} \times 5\frac{1}{2}$ inches, and is therefore amongst the largest at present known from this bed. It is somewhat triangular in general form, one surface being nearly flat, and is very much rounded and worn. On the weathered surface dark, purple, wavy lines appear, generally of the thickness of a sheet of writing paper, but sometimes a quarter, or even half an inch thick, alternating with lighter and thicker bands. Where broken the rock is more uniform in colour, the bands varying in shades of purple. Occasionally, where much weathered, the lighter bands show a tendency to columnar structure, developed perpendicularly to the planes of banding. The material is very hard, and not easily broken. The surface of the boulder is worn and smoothed, and in some parts may almost be said to be polished. Here and there the softer material of the light-coloured bands has been worn into small cavities or depressions, and in other places the lines of banding are brought into strong relief by a more uniform wearing away of the softer bands.

As is usually the case with the boulders and fossil remains of the Chloritic Marl, this specimen has upon its surface a number of attached plicatulæ and other small shells, and it bears also two patches of the phosphatic nodules characteristic of the bed from which it has been obtained, and even a fragment of the marl itself.

While the boulder has clearly been subjected to very great wear, and has the external appearance usually attributed to the action of ice when found in similar boulders of more recent periods, there are upon it no distinct or definite scratches or grooves.

Professor Bonney has kindly examined a fragment from this boulder. The material is a very compact quartz-felsite, containing small specks of quartz scattered in the matrix, which exhibits a distinct and interesting spherulitic structure. In concluding his notes on the boulder, Professor Bonney says:—'The microscopic structure of the rock differs very decidedly from any specimen which I have examined from Charnwood. It differs also from the old rhyolitic rocks of the Wrekin and of North Wales. Although it has a certain family likeness to all of these, enough to embolden one to suggest that it may have been derived from some volcanic mass, now lost to sight, which was active in the latest pre-Cambrian epoch, I cannot venture to refer it to any locality known to me in Britain. I have, however, no doubt that the pebble described by Mr. Watts' ('Geological Magazine,' vol. viii. p. 95) 'is from the same locality.'

Taken alone, no theory as to the prevalence or otherwise of floating ice in the sea of the period during which the lower part of the chalk was deposited can be founded on this particular boulder. But it at all events supports the already existing theory, based on the character of the boulders and pebbles already described from the Chloritic Marl. It has two characteristics of ice-borne erratics:—
1. It is superficially like boulders recognised as having been transported from distant sources by ice, and subjected to the peculiar wear and tear incident to ice-action.
2. Its material is derived from a parent rock which can under no probable circumstances have existed, at the period of the chalk, within a very considerable distance of its recently discovered resting-place. We may therefore fairly, I think, accept it as evidence of the probability of the existence of floating ice in the sea of the chalk period.

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8. *Report on the Fossil Phyllopoda of Palæozoic Rocks.*
See Reports, p. 215.

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9. *Fourth Report on the Tertiary Flora of the North of Ireland.*
See Reports, p. 209.

TUESDAY, SEPTEMBER 25.

The following Papers were read:—

1. *On a supposed case of Metamorphism in an Alpine Rock of Carboniferous Age. By* Professor T. G. BONNEY, *M.A.*, *F.R.S.*[1]

At the base of the Carboniferous series in some parts of the Western Alps is a conglomerate called the *poudingue de Val Orsine*, the matrix of which abounds in mica, and is supposed by some geologists to exhibit true foliation. The author had examined some typical localities near Vernayaz, and stated that the fragments consisted of vein-quartz, gneiss, and mica schist, resembling the crystalline rocks of the district, with some of an unaltered purplish slate. Further, microscopic examination showed that the ground mass exhibited no metamorphism of importance, but that the mica was also of fragmental origin. He also described a green flinty argillite from the same district, supposed to be a member of the Carboniferous series. This proved to have been composed originally of fragments much coarser than he should have expected from the aspect of the rock. These had been cracked and more or less crushed *in situ* by the pressure to which the whole district has been subjected, and had then undergone certain micro-mineralogical changes. He concluded by stating as the result of his investigations of the Alps, that there is always an abrupt transition from the comparatively unmetamorphosed rocks of known geological age to the true schists and gneisses of unknown but certainly far greater antiquity, and that nothing short of the clearest proof would justify us in considering any of the crystalline foliated rocks of the Alps as altered Devonian or Silurian, even if the latter term be used in its most extended sense.

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2. *Note on the Nagel-flue of the Rigi and Rossberg. By* Professor T. G. BONNEY, *M.A.*, *F.R.S.*[2]

The author called attention to the following points in regard to the conglomerate of these mountains:—(1) That the pebbles were not seldom indented by mutual pressure. This he considered, like the indentations common on the quartzite pebbles of the Bunter conglomerate of Central England, to be sufficient to show that such impressions did not indicate an early stage of metamorphism in the ordinary sense of that word, as argued last year by Professor James Thomson,[3] but were simply deformations due to long-continued pressure apart from any action of heat. (2) That the pebbles in this district consisted mainly of grits and limestones from the Secondary and perhaps early Tertiary series of the Alps, with a variable amount of a reddish granite (of whose locality he was ignorant). Alpine schists and gneisses were exceedingly rare. He concluded that the nagel-flue was deposited by a river, whose drainage area had some correspondence with that of the present Reuss, and its pebbles show that this Miocene river must have flowed almost wholly over the more modern Alpine rocks. These have now been stripped away from the underlying metamorphic series over a large extent of the basin of the Reuss. (3) That there was a close analogy between the Bunter conglomerate and the nagel-flue; the former also resembling the British Old Red Sandstone, and a part of the Calciferous sandstone series in Scotland. As these three were admittedly fresh-water deposits, he argued that the Bunter series (parts of which had some resemblance to the ordinary molasse) should be reckoned among the true fluviatile or fluvio-lacustrine deposits.

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3. *On the Pre-Cambrian Igneous Rocks of St. David's. By* Professor J. F. BLAKE, *M.A.*, *F.G.S.*

The rocks below the Cambrian conglomerate have been described by Dr. Hicks as bedded rocks belonging to three distinct periods. The same rocks

[1] Published *in extenso Geol. Mag.* Dec. ii. vol. x. p. 507.

[2] *Idem*, p. 511.

[3] *Report*, 1882, p. 536.

have been recently asserted by Dr. Geikie to be partly Cambrian and partly intrusive. The author contends that they are Precambrian in age, but form a very complete volcanic series, which may well be designated the Dimetian.

The basis of the series is the Dimetian granite, serving as the core. This is surrounded by the more acid rocks, as the quartz-felsites and felspar porphyries (the so-called Arvonian), and the more outlying portions consist of very varying materials, chiefly rough ashes or agglomerate breccias—on the east side finely bedded 'halleflintas,' and on the north side many basic lava flows. These are the so-called 'Pebdian.' The arrangement of these rocks shows the characteristic irregularity of volcanic rocks, and though many portions are bedded, they have no dominant strike over the whole district. The Cambrian series commencing with the conglomerates is quite independent and hangs together as a whole. In no place can a continuous passage be proved from the one series to the other; the junction is in most cases a faulted one, and at the places where this is not so, the conglomerate lies on different beds of the volcanic series.

The proofs of the Precambrian age of the volcanic series may be seen (1) between Nun's Chapel and Caerbwdy, where the junction is faulted towards the west, so that more and more of the series above the felspar-porphyries comes in towards the east, and the conglomerate contains fragments of it at Caerbwdy; (2) at Porthclais, and Ogof Llesugn, where the junctions are faulted, but the conglomerates hang to the Cambrian beds; (3) at Penmaen Melgn, where the conglomerate lies apparently without a fault, on the ashes and agglomerates which are not schistose; (4) at Castell, where the junction is faulted, the Cambrian striking at the volcanic series; (5) in Ramsey Island, where fragments of Arenig rocks, and conglomerate (of peculiar character) are equally let down amongst the ashes; (6) along the northern boundary of the mass, where different members of the Cambrian series come in contact with it.

The granite is nowhere intrusive, or in any way connected with the Cambrian rocks. It cannot even be proved intrusive in the volcanic series. The section at Ogof Llesugn shows a double fault of great magnitude forming the boundary of the granite as far as Porthclais, with a mass of conglomerate wedged in between the two faults, both of which are slickensided. The apparent welding of the conglomerate to the granite is due to the intrusion of the diabase along the fault which has caught up portions of each. This is the only place (except at Porthseli, where it has become schistose, perhaps by faulting) where there is any notable alteration in the quartz-conglomerate. The other junctions, whether at the faults or at the boundaries of the crystalline rocks, show little or no change. There is no proof of an isocline west of the granitic mass, but of a very variable series of ashes and lavas, with interstratified calcareous bands. None of the crystalline portions of the series show any signs of true bedding. The Cambrian beds which can be compared to tuffs, though they have not been proved to be such, are far away from the base of the series, and bear no relation to the underlying ashes.

Similar phenomena to these are repeated further to the east, in the localities pointed out by Dr. Hicks. Hence in these ancient times there was a tendency to a linear arrangement of volcanic outbursts—the central and older portions are more crystalline and acid, while the ashes and more basic flows, with the stratified siliceous tuffs, form the outworks round each centre. On the possibly denuded surface of these rocks the Cambrian beds were deposited, the conglomerates deriving at least their matrix from them; and at a later date the vertical direction was given to them by the forcing up of the great volcanic series to their level, in some places the granitic base, at others only the ashy surface. At this, or at some later period, the diabase dykes invaded both.

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4. *On the Geology of the Troad.* *By* J. S. Diller.

This paper gave a brief account of recent researches in the Troad, the author being attached as geologist to the United States Assos Expedition. Further details, especially as regards the igneous rocks, were submitted to the Geological

Society of London in May last;[1] other notices on the subject have been published in the papers of the Archæological Institute of America.

The oldest rocks of the Troad are the crystalline schists with limestones which form the Ida range (5,750 feet), and which also appear in smaller and lower areas elsewhere. From the limestone-beds of this series, on the flanks of Ida, most of the springs arise which are the sources of the chief rivers of the Troad. The age of this series is unknown; it is probably Archæan.

Resting unconformably upon these beds, and in part composed of them, is a newer series of partially altered rocks, which may range in age from Palæozoic to Eocene; but this series requires more examination.

The Upper Tertiaries are sharply marked off from these older rocks; they occur in two separate areas. The older series is marine; it is found mainly along the western and north-western part of the Troad. These beds belong to the Sarmatian stage—Upper Miocene. The newer Tertiary series is composed of fresh-water beds, Upper Miocene or Lower Pliocene, occurring mainly in the interior of the country, and especially along the plane of the Mendere.

The oldest igneous rock is *granite*, which invades and alters the oldest (? Archæan) crystalline rocks. Dykes of *quartz-porphyry* intersect this. *Quartz-diorite* invades the second, or partially crystalline, sedimentary series.

Of the newer igneous rocks *andesites* and *liparites* are the oldest; where they can be studied together the latter is the later of the two. Of later date are *basalts* and *nepheline basalts.*

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5. *On the Causes of Change of Climature during Long Periods of Time, and of Coincident Changes of Fauna and Flora.* By JOHN GUNN.[2]

The object is to show that, as the elevation of mountain-ranges is the principal cause of cold, so the converse is true—namely, that their subsidence, in long periods of time, is the cause of warm temperatures.

Without attempting to account for the origin of the inequalities of the earth's surface, or to throw any light upon the cause of the upheaval of the land, the author endeavours to prove the reality of his proposition, and commences with the Carboniferous period.

There is evidence of a normal and quiescent state during which coal was deposited; not an instance can be adduced of an ice-scratched boulder, but a mild and subtropical climate appears to have prevailed.

Passing to the Permian, the change both of fauna and flora appears to be coincident with that of the level of the land. A great and general disturbance took place, and glaciated and striated rocks prove the reality of a Glacial period, as observed by Professor Ramsay.

From that era, and throughout the oolitic series, a gradual and general levelling occurred, and there is no appearance of scratched boulders. Marsupial animals attest a subtropical surface of the land, and saurians indicate the like condition of the sea. Throughout the Purbeck beds the marsupial form is continued, and in the Dirt-bed of the Isle of Portland the Zamia represents a tropical flora.

The same remarks may be made respecting the prevalence of a warm climate during the cretaceous series. The chalk was laid down in a warm sea horizontally, and its elevation into its present inclined and irregular position was accompanied with a lowering of the climate and concurrent change of fauna and flora.

The Eocene and still more the Miocene formations exhibit very gradually but decidedly the effect of change of level and disturbance of the strata, but no striated boulders that the writer is aware of, nor any indication of ice-action have been discovered in them.

But the effect of such changes becomes more obvious in Pliocene times; and in no part of the world are there the like facilities for observation as in the eastern counties of England. There, from the continuity of the strata, the relations of cause and effect are minutely traceable, and it may be clearly seen how the varia-

[1] *Quart. Journ. Geol. Soc.* vol. xxxix. p. 627, with Geol. Map; Appendix by W. Topley.
[2] Published *in extenso Geol. Mag.* Dec. iii. vol. i. p. 73.

tions of the climate and of the fauna and flora have gone *pari passu* with the elevation of the land. This is exemplified in the variety of the elephantine and cervine remains which were successively entombed in the great Anglo-Belgian basin. After that deposit the land was evidently upheaved, so that on the west the estuary was raised high and dry without the river, and on the east there is the remnant of the mighty Rhine without the estuary.

A severance has taken place, caused by this elevatory process, between the elephantine and cervine remains on either side of the Alpine ranges. This may be seen in Germany, Italy, and other countries on the east, and in the Thames valley, the Forest-bed in England, and in several districts in France and elsewhere on the west. Both mammals and molluscs had an extensive range before the mountains were raised and intercommunication was cut off.

The result of this upheaval was the introduction of the so-called Glacial epoch, when the greater part of the mammals succumbed to the cold, and an ice-sheet by land and glaciers by sea spread the temperature of the Ice Age far and wide.

The reality of this scene and its cause are shown by the gradual introduction of the present milder temperature, which has succeeded on the wearing down of the level of perpetual snow and the retreat of glaciers. This may be observed by every traveller in Switzerland, Savoy, Italy, and Greece; and we appear to have returned to the same temperature as prevailed during the Forest-bed period after having experienced here the severity of subarctic regions.

In Central North America the elevation of the land, 2,000 feet, has sufficed to change the course of the Gulf Stream. By this the current of warm water is diverted to its present course, and we now enjoy the benefits which once spread their genial influence in the direction of Melville Island. This change suggests the best solution of that extraordinary phenomenon the growth of coal-plants in so northerly a latitude.

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6. *Preliminary Note on the further discovery of Vertebrate Footprints in the Penrith Sandstone. By* GEORGE VARTY SMITH.

For some time past the author had been endeavouring to find footprints in the Penrith sandstone, knowing that impressions of the same nature as those met with in the equivalent strata of Dumfries had been previously found at Brownrigg in Plumpton, about five miles to the north of Penrith, and that similar impressions had also been noticed by the late Mr. Binney and by Prof. Harkness on the flaggy beds near Penrith, but that those impressions were not so distinct as at Brownrigg.

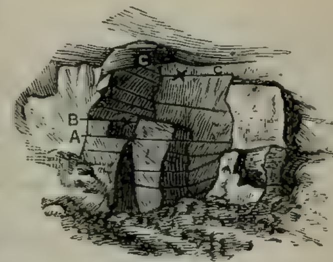
Last May he was fortunate enough to meet with some impressions in a quarry which had been opened out when the Settle and Carlisle branch of the Midland Railway was in course of construction. This quarry is situated on the slope of the hill north of the highway from Penrith to Alston, and about three and a half miles east from Penrith. The rock consists wholly of strongly false-bedded red sandstone, similar in character to that so largely employed for building purposes in and around the town of Penrith.

The geological position of the sandstone was shown approximately in the diagram which was exhibited. It is important to notice that the Penrith sandstone occurs beneath the magnesian limestone, the latter being found in the bank of the river Eden between Throstle Hall and Little Salkeld, to the north-east of the quarry, as well as in Hilton Beck, near Appleby. Nearly all the footprints hitherto found in the New Red have been obtained from the so-called Trias, and it is of great interest to find vestiges of a similar nature occurring in rocks clearly older than the magnesian limestone.

Facsimile casts of several impressions, showing the peculiar characteristics of each, were exhibited at the meeting, together with sketches of the stones upon which the impressions occur, serving to show the direction of the tracks.

The first impression (cast No. 1) was found loose on the top of the bed where the workmen had been quarrying. From the impressions subsequently found *in situ* it would appear to be the cast, or top stone. Subsequently the author found impressions on the bed marked A in the water-colour sketch of the quarry.

The casts Nos. 2 and 3 are from the bed marked A in the annexed sketch of the quarry. No. 4 is from bed B, and Nos. 5, 6, and 7 are from the bed C. The casts Nos. 8 and 9 are of stones taken from the same quarry by the workmen, but they informed the author that the original of No. 9 was found below bed A, and was a bottom stone. The impressions in the three beds take the same, or nearly the same, direction.



LOOKING S.W.

The impressions seen in the casts 1, 3, and 5 appear to be those of similar animals, which evidently used their fore feet simply as supports, while throwing the weight of their bodies mainly on their hind feet, which when in motion over-reached the impressions left by the fore feet. Nos. 2 and 6 to all appearance do not exhibit the same character, the impressions being probably those of a single foot; those on No. 6 would appear to be the impression of a pad and three digits. The impressions on No. 4, being of more uniform depth, would appear to have been made by an animal which threw its weight pretty equally on all four feet. The impressions on No. 7 appear different again, and to have been those of a much smaller animal. It is important to note that the impressions Nos. 5, 6, and 7, being all different, occur on the same stone. The impressions on No. 8 are from their position very different to any of the others. It seems doubtful whether each impression on No. 9 is that of a single foot, or whether it is not rather that of both the fore and hind feet nearly in coincidence. The appearance of a double row of toes and the abnormal number of six digits visible in some impressions probably arises from the placing of the hind foot nearly in the impression left by the forefoot; or, again, the impression may represent the pad and toes of a single foot. It is of interest to note the variety of forms of animal life represented in the present specimens, a variety that compares very favourably with the small range of forms represented by the impressions hitherto obtained from rocks higher in the series. It has been suggested that these represent the vestiges of at least several different species, if not of different genera, of extinct vertebrates.

I had, previously to this, found an impression (No. 10) in the higher number of the same series overlying the magnesian limestone, and known as the St. Bee's sandstone, about a mile south-west of the village of Hilton, on the road to Appleby. It was not *in situ*, but a subsequent visit to the same place convinced me that it must have been quarried from a quarry on the spot. The same quarry has yielded several stones exhibiting desiccation-marks and also portions of footprints.

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7. *Archæastacus Willemœsii, a New Genus of Eryonidæ.* *By* C. Spence Bate, *F.R.S.*

The species of Eryon hitherto described seem to belong to separate genera, as different from one another as from some recent forms.

The specimen now described is from the Lower Lias of Lyme Regis, and it seems to connect the fossil forms with those recent ones brought to light, through deep-sea exploration, more than any other form does.

The animal appears to have had no eye, but the presence of an orbital concavity shows that it has retrograded from a species in which the eye was an important feature.

The genus is allied to *Polycheles*, which it resembles as much as it does the ancient *Eryon*.

It seems, therefore, that *Eryon* has departed from an unknown ancestor of *Astacus*, and that the recent *Polycheles* is in direct descent from the Liassic *Archæastacus*.

Section D.—BIOLOGY.

President of the Section—Professor E. Ray Lankester, M.A., F.R.S., F.L.S.

THURSDAY, SEPTEMBER 20.

The President delivered the following Address:—

It has become the custom for the presidents of the various sections of this Association to open the proceedings of the departments with the chairmanship of which they are charged, by formal addresses. In reflecting on the topics which it might be desirable for me to bring under your notice, as your president, on the present occasion, it has occurred to me that I might use this opportunity most fitly by departing somewhat from the prevailing custom of reviewing the progress of science in some special direction during the past year; and that instead of placing before you a summary of the results recently obtained by the investigations of biologists in this or that line of inquiry, I might ask your attention and that of the external public (who are wont to give some kindly consideration to the opinions expressed on these occasions) to a matter which is even more directly connected with the avowed object of our Association, namely, 'the Advancement of Science.' I propose to place before you a few observations upon the provision which exists in this country for the advancement of that branch of science to which Section D is dedicated—namely, Biology.

I am aware that it is usual for those who speak of men of science and their pursuits to ignore altogether such sordid topics as the one which I have chosen to bring forward. A certain pride on the one hand, and a willing acquiescence on the other hand, usually prevents those who are professionally concerned with scientific pursuits from exposing to the public the pecuniary destitution and the consequent crippling and languor of scientific research in this country. Those Englishmen who take an interest in the progress of science are apt to suppose that, in some way which they have never clearly understood, the pursuit of scientific truth is not only its own reward, but also a sufficient source of food and clothing. Whilst they are interested and amused by the remarkable discoveries of scientific men, they are astonished whenever a proposal is mentioned to assign salaries to a few such persons, sufficient to enable them to live decently whilst devoting their time and strength to investigation. The public are becoming more and more anxious to have the opinion or report of scientific men upon matters of commercial importance, or in relation to the public health; and yet in ninety-nine cases out of a hundred they expect to have that opinion for the asking, although accustomed to pay cther professional men handsomely for similar service. There is, it appears, in the public mind a vague belief that men who occupy their time with the endeavour to add to knowledge in this or that branch of science are mysteriously supported by the State exchequer, and are thus fair game for attacking with all sorts of demands for gratuitous service; or, on the other hand, the notion at work appears sometimes to be that the making of new knowledge—in fact, scientific discovery—is an agreeable pastime, in which some ingenious gentlemen, whose business in other directions takes up their best hours, find relaxation after dinner or on the spare hours of Sunday. Such mistaken views ought to be dispelled with all possible celerity and determination. It is in part owing to the fact that the real state of the case is not widely and persistently made known to the public, that no attempt is made in this country

to raise scientific research, and especially biological research, from the condition of destitution and neglect under which it suffers—a condition which is far below that of these same interests in France and Germany, and even in Holland, Belgium, Italy, and Russia, and is discreditable to England in proportion as she is richer than other States.

It appears to me that, in placing this matter before you, I may remove myself from any suggestion of self-interest by at once stating that the great defect to which I shall draw your attention is *not* that the few existing public positions which are open in this country to men who intend to devote their chief energies to biological research are endowed with insufficient salaries; but that there is not anything like *a sufficiently large number* of those posts, and that there is in that respect, from a national point of view, a pecuniary starvation of biology, a withholding of money which (to use another metaphor) is no less the sinews of the war of science against ignorance than of other less glorious campaigns. Surely men engaged in the scientific profession may advocate the claim of science to maintenance and needful pecuniary provision! It seems to me that we should, if necessary, swallow, rather than be controlled by, that pride which tempts us to paint the scientific career as one far above and independent of pecuniary considerations; whereas all the while we know that knowledge is languishing, that able men are drawn off from scientific research into other careers, that important discoveries are approached and their final grasp relinquished, that great men depart and leave no disciples or successors, simply for want of that which is largely given in other countries, of that which is most abundant in this country, and is so lavishly expended on armies and navies, on the development of commercial resources, on a hundred injurious or meaningless charities—viz., money.

I have no doubt that I have the sympathy of all my hearers in wishing for more extensive provision in this country for the prosecution of scientific research, and especially of biological research. I need hardly remind this audience of the almost romantic history of some of the great discoveries which have been made in reference to the nature and history of living things during the past century. The microscope, which was a drawing-room toy a hundred years ago, has, in the hands of devoted and gifted students of nature, been the means of giving us knowledge which, on the one hand, has saved thousands of surgical patients from terrible pain and death, and, on the other hand, has laid the foundation of that new philosophy with which the name of Darwin will for ever be associated. When Ehrenberg and, later, Dujardin described and figured the various forms of Monas, Vibrio, Spirillum, and Bacterium which their microscopes revealed to them, no one could predict that fifty years later these organisms would be recognised as the cause of that dangerous suppuration of wounds which so often defeated the beneficent efforts of the surgeon and made an operation in a hospital ward as dangerous to the patient as residence in a plague-stricken city. Yet this is the result which the assiduous studies of the biologists, provided with laboratories and maintenance by continental States, have in due time brought to light. Theodore Schwann, professor at Liège, first showed that these Bacteria are the cause of the putrefaction of organic substances, and subsequently the French chemist Pasteur, professor in the École Normale of Paris, confirmed and extended Schwann's discovery, so as to establish the belief that all putrefactive changes are due to such minute organisms, and that if these organisms can be kept at bay no putrefaction can occur in any given substance.

It was reserved for our countryman Joseph Lister to apply this result to the treatment of wounds, and by his famous antiseptic method to destroy by means of special poisons the putrefactive organisms which necessarily find their way into the neighbourhood of a wound, or of the surgeon's knife and dressings, and to ward off by similar means the access of such organisms to the wounded surface. The amount of death, not to speak of the suffering short of death, which the knowledge of Bacteria gained by the microscope has thus averted is incalculable.

Yet further, the discoveries of Ehrenberg, Schwann, and Pasteur are bearing fruit of a similar kind in other directions. It seems in the highest degree probable that the terrible scourge known as tubercular consumption or phthisis is due to a parasitic Bacterium (Bacillus), discovered two years since by Koch of Berlin, as the im-

mediate result of investigations which he was commissioned to carry on at the public expense, in the specially erected Laboratory of Public Health, by the German Imperial Government. The diseases known as erysipelas and glanders or farcy have similarly, within the past few months in German State-supported laboratories, been shown to be due to the attacks of special kinds of Bacteria. At present this knowledge has not led to a successful method of combating those diseases, but we can hardly doubt that it will ultimately do so. We are warranted in this belief by the fact that the disease known as 'splenic fever' in cattle and 'malignant pustule' or anthrax in man has likewise been shown to be due to the action of a special kind of Bacterium, and that this knowledge has, in the hands of MM. Toussaint and Pasteur, led to a treatment in relation to this disease similar to that of vaccination in relation to small-pox. By cultivation a modified growth of the anthrax parasite is obtained, which is then used in order to inoculate cattle and sheep with a mild form of the disease, such inoculation having the result of rendering the cattle and sheep free from the attacks of the severe form of disease, just as vaccination or inoculation with cow-pox protects man from the attack of the deadly small-pox. One other case I may call to mind in which knowledge of the presence of Bacteria as the cause of disease has led to successful curative treatment. A not uncommon affliction is inflammation of the bladder accompanied by ammoniacal decomposition of the urine. Microscopical investigation has shown that this ammoniacal decomposition is entirely due to the activity of a Bacterium. Fortunately this Bacterium is at once killed by weak solutions of quinine, which can be injected into the bladder without causing any injury or irritation. This example appears to have great importance, because it is the fact that many kinds of Bacteria are not killed by solutions of quinine, but require other and much more irritant poisons to destroy their life, which could not be injected into the bladder without causing disastrous effects. Since some Bacteria are killed by one poison and some by another, it becomes a matter of the keenest interest to find out all such poisons; and possibly among them may be some which can be applied so as to kill the Bacteria which produce phthisis, erysipelas, glanders, anthrax, and other scourges of humanity, whilst not acting injuriously upon the body of the victim in which these infinitesimal parasites are doing their deadly work. In such ways as this biology has turned the toy 'magnifying-glass' of the last century into a saver of life and health.

No less has the same agency revolutionised the thoughts of men in every branch of philosophy and speculation. The knowledge of the growth of the chick from the egg and of other organisms from similarly constituted beginnings has been slowly and continuously gained by prodigious labour, extending over generation after generation of students who have occupied the laboratories and lived on the stipends provided by the Governments of European States—not English, but chiefly German. It is this history of the development of the individual animal and plant from a simple homogeneous beginning to a complex heterogeneous adult which has furnished the starting-point for the wide-reaching Doctrine of Evolution. It is this knowledge, coupled with the knowledge of the myriad details of structure of all kinds of animals and plants which the faithful occupants of laboratories and the guardians of biological collections have in the past hundred years laboriously searched out and recorded—it is this which enabled Darwin to propound, to test, and to firmly establish his theory of the origin of species by natural selection, and finally to bring the origin, development, and progress of man also into the area of physical science. I have said enough, in referring only to two very diverse examples of the far-reaching consequences flowing from the discoveries of single-minded investigators in biological science, to remind my hearers that in the domain of biology, as in other sciences, the results attained by those who have laboured simply to extend our knowledge of the structure and properties of living things, in the faith that every increase of knowledge will ultimately bring its blessing to humanity, have in fact led with astonishing rapidity to conclusions affecting most profoundly both the bodily and the mental welfare of the community.

We who know the beneficent results which must flow more and more from the labours of those who are able to create new knowledge of living things, or, in other

words, are able to aid in the growth of biological science, must feel something more than regret—even indignation—that England should do so small a proportion of the laborious investigation which is necessary, and is being carried on for our profit by other nationalities. It must not be supposed, because we have had our Harvey and our Darwin, our Hunter and our Lister, that therefore we have done and are doing all that is needful in the increase of biological science. The position of this country in relation to the progress of science is not to be decided by the citation of great names.

We require to look more fully into the matter than this. The question is not whether England has produced some great discoverers, or as many as any other nationality, but whether we might not with advantage to our own community and that of the civilised world generally, do far more in the field of scientific investigation than we do.

It may be laid down as a general proposition, to which I know of no important exception, that scientific discovery has only been made by one of two classes of men, namely—(1) those whose time could be devoted to it in virtue of their possessing inherited fortunes; (2) those whose time could be devoted to it in virtue of their possessing a stipend or endowment especially assigned to them for that purpose.

Now it is a very remarkable fact that in England, far more than in any other country, the possessors of private fortunes have devoted themselves to scientific investigation. Not only have we in all parts of the country numerous *dilettanti*[1] who, especially in various branches of biology, do valuable work in continually adding to knowledge, quietly pursuing their favourite study without seeking to reach to any great eminence, but it is the fact that many of the greatest names of English discoverers in science are those of men who held no professional position designed to maintain an investigator, but owed their opportunity simply to the fact that they enjoyed a more or less ample income by inheritance. Thus, Harvey possessed a private fortune, Darwin also, and Lyell. Such also is true of some of the English naturalists, who more recently have most successfully devoted their energies to research. Those who wish to defend the present neglect of the Government and of public institutions to provide means for the carrying on of scientific research in this country, are accustomed to declare as a justification for this neglect that we do very well without such provision, inasmuch as the cultivation of science here flourishes in the hands of those who are in a position of pecuniary independence. The reply to this is obvious. If those few of our countrymen who by accident are placed in an independent position show such ability in the prosecution of scientific research, how much more would be effected in the same direction were the machinery provided to enable those also who are *not* accidentally favoured by fortune to enter upon the same kind of work. The number of wealthy men who have distinguished themselves in scientific research in England is simply evidence that there is a natural ability and liking for such work in the English character, and is a distinct encouragement to those who have it in their power to do so, to offer the opportunity of devoting themselves to research to a larger number of the members of the community. It is impossible to doubt that there are hundreds of men amongst us who have as great capacity for scientific discovery as those whom fortune has favoured with leisure and opportunity. It cannot be doubted that were the means provided to enable even a proportion of such men to give themselves up to scientific investigation, great discoveries of no less importance to the world than those relative to the causes of disease and the development of living things from the egg—which I have cited—would be made as a direct consequence of their activity, whereas now we must wait until in due course of time these discoveries shall be made for us in the laboratories of Germany, France, or Russia.

It should further be pointed out that it is altogether a mistake to suppose that

[1] I use this word in its best and truest sense, and would refer those who have been accustomed to associate with it some implication of contempt, to the wise and appreciative remarks of Goethe on "Dilettanti."

the existence amongst us of a few very eminent men is any evidence that we are contributing largely to the hard work of careful study and observation which really forms the material upon which the conclusions of eminent discoverers are based. You will find in every department of biological knowledge, that the hard work of investigation is being carried on by the well-trained army of German observers. Whether you ask the zoologist, the botanist, the physiologist, or the anthropologist, you will get the same answer: it is to German sources that he looks for new information; it is in German workshops that discoveries, each small in itself, but gradually leading up to great conclusions, are daily being made. To a very large extent the business of those who are occupied with teaching or applying biological science in this country consists in making known what has been done in German laboratories; our English students flock to Germany to learn the methods of scientific research; and to such a state of weakness is English science reduced for want of proper nurture and support, that even on some of the rare occasions when a capable investigator of biological problems has been required for the public service, it has been necessary to obtain the assistance of a foreigner trained in the laboratories of Germany.

Let me now briefly explain what are the arrangements, in number and in kind, which exist in other countries for the purpose of promoting the advancement of biological science, which are wanting in this country.

In the German Empire, with a population of 45,000,000, there are twenty-one universities. These universities are very different from anything which goes by the name in this country. Amongst its other arrangements devoted to the study and teaching of all branches of learning and science, each university has five institutes, or establishments, devoted to the prosecution of researches in biological science. These are respectively the physiological, the zoological, the anatomical, the pathological, and the botanical. In one of these universities of average size each of the institutes named consists of a spacious building containing many rooms fitted as workshops, provided with instruments, a museum, and, in the last instance, with an experimental garden. All this is provided and maintained by the State. At the head of each institute is the university professor respectively of physiology, of zoology, of anatomy, of pathology, or of botany. He is paid a stipend by the State, which in the smallest university is as low as 120*l*., but may be in others as much as 700*l*., and averages say 400*l*. a year. Considering the relative expenditure of the professional classes in the two countries, this average may be taken as equal to 800*l*. a year in England.[1] Besides the professor, each institute has attached to it, with salaries paid by the State, two qualified assistants, who in course of time will succeed to independent positions. A liberal allowance is also made to each institute by the State for the purchase of instruments, material for study, and for the pay of servants, so that the total expenditure on professor, assistants, laboratory service, and maintenance, averages 800*l*. a year for each institute—reaching as much as 2,000*l*. or 3,000*l*. a year in the larger universities. It is the business of the professor, in conjunction with his assistants and the advanced students, who are admitted to work in the laboratories free of charge, to carry on investigations, *to create new knowledge* in the several domains of physiology, zoology, anatomy, pathology, and botany. It is for this that the professor receives his stipend, and it is on his success in this field of labour that his promotion to a more important or better paid post in another university depends. In addition to and irrespectively of this part of his duties, each professor is charged with the delivery of courses of lectures and of elementary instruction to the general students of the university, and for this he is allowed to charge a certain fee to each student, which he receives himself; the total of such fees may, in the case of a largely attended university and a popular subject, form a very important addition to the professorial income; but it is distinctly to be understood that such payment

[1] From the fact that the salaries of judges, civil servants, military and naval officers, parsons and schoolmasters, as also the fees of physicians and lawyers, are in Germany even less than half what is paid to the same classes in England, I think that we are justified in making this estimate.

by fees is only an *addition* to the professor's income, quite independent of his stipend and of his regular occupation in the laboratory: it is paid from a separate source and for a separate object. There are thus in the German Empire more than 100 such institutes devoted to the prosecution of biological discovery, carried on at an annual cost to the State of about 80,000*l.*, equal to about 160,000*l.* in England, providing posts of graduated value for 300 investigators, some of small value, sufficient to carry the young student through the earlier portion of his career, whilst he is being trained and acting as the assistant of more experienced men—others forming the sufficient but not too valuable prizes which are the rewards of continuous and successful labour.

In addition to these university institutes, there are in Germany such special laboratories of research, with duly salaried staff of investigators, as the Imperial Sanitary Institute of Berlin, and the large museums of Berlin, Bremen, and other large towns corresponding to our own British Museum of Natural History.

Moreover, we must be careful to note, in making any comparison with the arrangements existing in England, that there are, in addition to the universities in Germany, a number of other educational institutions, at least equal in number, which are known as polytechnic schools, technical colleges, and agricultural colleges. These furnish posts of emolument to a limited number of biological students, who give courses of instruction to their pupils, but they have not the same arrangements for research as the universities, and are closely similar to those colleges which have been founded of late years in the provincial towns of England, such as Bristol, Nottingham, and Leeds. The latter are sometimes quoted by sanguine persons, who are satisfied with the neglected condition of scientific training and research in this country, as really sufficient and adequate representatives of the German universities. As a matter of fact, the excellent English colleges in question do not present anything at all comparable to the arrangements of a German university, and are, in respect of the amount of money which is expended upon them, the number of their teaching staff and the efficiency of their laboratories, inferior not merely to the smallest German university, but inferior to many of the technical schools of that country.

Passing from Germany, I would now ask your attention for a moment to an institution which is supported by the French Government, and which—quite irrespective of the French university system, which is not on the whole superior to our own—constitutes one of the most effective arrangements in any European State for the production of new knowledge. The institution to which I allude is the Collège de France in Paris—co-existing there with the Sorbonne, the École de Médecine, the École Normale, the Jardin des Plantes, and other State-supported institutions—in which opportunity is provided for those Frenchmen who have the requisite talent to pursue scientific discovery in the department of biology, and in other branches of science. I particularly mention the Collège de France, because it appears to me that the foundation of such a college in London would be one of the simplest and most direct steps that could be taken towards filling, in some degree, the void from which English science suffers. The Collège de France is divided into a literary and a scientific faculty. Each faculty consists of some twenty professors. Each professor in the scientific faculty is provided with a laboratory and assistants (as many as four assistants in some cases), and with a considerable allowance for the expenses of the instruments and materials required in research. The personal stipend of each professor is 400*l.*, which has been increased by an additional 100*l.* a year in some cases from the Government Department charged with the promotion of higher studies. The professors in this institution, as in the German universities, when a vacancy occurs, have the right of nominating their future colleague, their recommendation being accepted by the Government. The professors are not expected to give any elementary instruction, but are directed to carry on original investigations, in prosecuting which they may associate with themselves pupils who are sufficiently advanced to join in such work; and it is further the duty of each professor to give a course of forty lectures in each year upon the results of the researches in which he is engaged. There are at present among the professors of the Collège de France four of the most distinguished

among contemporary students of biological science: Professor Brown-Séquard, Professor Marey, Professor Balbiani, and Professor Ranvier. Everyone who is acquainted with the progress of discovery in physiology, minute anatomy, and embryology, will admit that the opportunities afforded to these men have not been wasted: they have, as the result of the position in which they have been placed, produced abundant and most valuable work, and have, in addition, trained younger men to carry on the same line of activity. It was here, too, in the Collège de France, that the great genius of Claude Bernard found the necessary conditions for its development.

Let us now see how many and what kind of institutions there are in England devised so as to promote the making of new knowledge in biological science. Most persons are apt to be deceived in this matter by the fact that the terms 'university,' 'professorship,' and 'college' are used very freely in England in reference to institutions which have no pecuniary resources whatever, and which, instead of corresponding to the German arrangements which go by these names, are empty titles, neither backed by adequate subsidy of the State nor by endowment from private sources.

In England, with its 25,000,000 inhabitants, there are only four universities which possess endowments and professoriates—viz., Oxford, Cambridge, Durham, and the Victoria (Owens College). Besides these, which are variously and specially organised each in its own way, there are the London Colleges (University and King's), the Normal School of Science at South Kensington, and various provincial colleges, which are to a small and varying extent in possession of funds which could be or are used to promote scientific research. Amongst all these variously arranged institutions there is an extraordinarily small amount of provision for biological research. In London there is one professorship only, that at the Normal School of Science, which is maintained by a stipend paid by the State, and has a laboratory and salaried assistants, similarly maintained, in connection with it. The only other posts in London which are provided with stipends intended to enable their holders to pursue researches in the domain of biological science, are the two chairs of physiology and of zoology at University College, which, through the munificence of a private individual,[1] have been endowed to the extent of 300*l.* a year each. To these should be added, in our calculation, certain posts in connection with the British Museum of Natural History and the Royal Gardens at Kew, maintained by the State; though it must be remembered that a large part of the expenditure in those institutions is necessarily taken up in the preservation of great national collections, and is not applicable to the subvention of investigators. We may, however, reckon about six posts, great and small, in the British Museum, and four at Kew, as coming into the category which we have in view. In London, then, we may reckon approximately some fourteen or fifteen subsidised posts for biological research. In Oxford there fall under this category the professorship of anatomy and his assistant, that of physiology, that of zoology, that of botany. The Oxford professorships are well supported by endowment, averaging 700*l.* or 800*l.* a year; but they are inadequately provided with assistants as compared with corresponding German positions. Whilst Oxford has thus five posts, Cambridge has at present the same number, though the stipends are of less average value. In regard to Durham, it does not appear that the biological professorships (which have their seat in the Newcastle College of Science) are supported by stipends derived from endowment: they fall under another category, to which allusion will be made below, of purely teaching positions, supported by the fees paid for such teaching by pupils. The Victoria University (Owens College, Manchester) supports its professors of physiology, anatomy, zoology, botany, and pathology, by means partly of endowment, partly of pupils' fees. By the provision of adequate laboratories and of salaries for assistants to each professor, and of student-fellowships, Owens College gives direct support to original investigation. We may reckon five major and eight minor posts as dedicated to biological research in this college. Altogether, then, we have 15 positions in London and 23 in the provinces (taking assistantships, and

[1] Mr. Jodrell.

professorships, and curatorships together)—a total of 38 in all England with its 25,000,000 inhabitants, as against the 300 in Germany with 45,000,000 inhabitants. In proportion to its population (leaving aside the consideration of its greater wealth), England has only about one-fourth of the provision for the advancement of biological research which exists in Germany.

It would not be fair to reckon in this comparison the various biological professorships in small colleges recently created, and paid to a small extent by stipends derived from endowments, in the provincial towns of England: for the holders of these chairs are called upon to teach a variety of subjects, for instance, zoology, botany, and geology combined; and not only is the devotion of the energies of their teaching staff to scientific discovery not contemplated in the arrangement of these institutions, but, as a matter of fact, the large demands made on the professors in the way of teaching must deprive them of the time necessary for any serious investigation. Such posts, in the fact that neither time, assistants, nor proper laboratories are provided to enable their holders to engage in scientific research, are schoolmasterships rather than professorships, as the word is used in German universities.

One result of the exceedingly small provision of positions in England similar to those furnished by the German university system, and of the irregular, uncertain character of many of those which do exist, is that there is an insufficient supply of young men willing to enter upon the career of zoologist, botanist, physiologist or pathologist as a profession. The number of posts is too small to create a profession, *i.e.* an avenue of success; and consequently, whereas in Germany there is always a large body of new men ready to fill up the vacancies as they occur in the professorial organisation, in England it very naturally does not appear to our university students as a reasonable thing to enter upon research as a profession, when the chances of employment are so few and far between.

Before stating, as I propose to do, what appears to me a reasonable and proper method of removing to some extent the defect in our national life due to the want of provision for scientific research, I will endeavour to meet some of the objections which are usually raised to such views as those which I am advocating. The endowment of research by the State, or from public funds of any kind, is opposed on various grounds. One is that such action on the part of the Government is well enough in continental States, but is contrary to the spirit of English statecraft, which leaves scientific as well as other *enterprise* to the individual initiative of the people. This objection is based on error, both as to fact and theory. It is well enough to leave to individual effort the conduct of such enterprises as are remunerative to the parties who conduct them; but it is a mistake to speak of scientific research as an 'enterprise' at all. The mistake arises from the extraordinary pertinacity with which so-called 'invention' is confounded with the discovery of scientific truth. New knowledge in biological or other branches of science cannot be sold; it has no marketable value. Koch could not have sold the discovery of the Bacterium of phthisis for as much as sixpence, had he wished to do so. Accordingly, we find that there is not, and never has been, any tendency among the citizens of this country to provide for themselves institutions for the manufacture of an article of so little pecuniary value to the individual who turns it out as is new knowledge. On the other hand, as a matter of fact, the providing of means for the manufacture of that article is not only not foreign to English statecraft, but is largely, though not largely enough, undertaken by the English State. The Royal Observatories, the British Museum, the Royal Gardens at Kew, the Geological Survey, the Government grant of 4,000*l.* a year to the Royal Society, the 300*l.* or 400*l.* a year (not a large sum) expended through the medical officer of the Privy Council upon the experimental investigation of disease, are ample evidence that such providing of means for creating new knowledge forms part of the natural and recognised responsibilities of the British Government. Such a responsibility clearly is recognised in this country, and does fall, according to the present arrangement of things, upon the central Government. What we have to regret is, that those who temporarily hold the reins of government fail to perceive the lamentable inadequacy of the mode in which this responsibility is met.

A second objection which is made to the endowment of research by public

funds, or by other means, such as voluntary contributions, is this: it is stated that men engaged in scientific research ought to *teach*, and thus gain their livelihood. It is argued, in fact, that there is no need whatever to provide stipends or laboratories for researchers, since they have only to stand up and teach in order to make incomes sufficient to keep them and their families, and to provide themselves with laboratories. This is a very plausible statement, because it is the fact that some investigators have also been excellent lecturers, and have been able to make an income by teaching whilst carrying on a limited amount of scientific investigation. But neither by teaching in the form of popular lectures, nor by teaching university or professional students who desire as a result to pass some examination test, is it possible, where there is a fair field and no favour, for a man to gain a reasonable income and at the same time to leave himself time and energy to carry on original investigations in science.

In some universities, such as those of Scotland, the privilege of conferring degrees of pecuniary value to their possessors becomes a source of income to the professors of the university; they are, in fact, able to make considerable incomes, independently of endowment, by compelling the candidates for degrees to pay a fee to each professor in the faculty for the right of attending his lectures and of presentation to the degree. Consequently, teaching here appears to be producing an income which may support a researcher; in reality, it is the acquisition of the university degree, and not necessarily the teaching, for which the pupil pays his fee. Where the teacher is unprotected by any compulsory regulations (such as that which requires attendance on his lectures and fee-payment on the part of the pupils) it is *impossible* for him to obtain such an income by teaching for one hour a day as will enable him to devote the rest of the day to unremunerative study and investigation, for the following reason. Other teachers, equally satisfactory as teachers, will enter into competition with him, without having the same intention of teaching for one hour only, and of carrying on researches for the rest of the day. They will contemplate teaching for six hours a day, and they will accordingly offer to those who require to be taught either six hours' teaching for the same fee which the researcher charges for one, or one hour for a sixth part of that fee. Consequently the unprotected researcher will find his lecture-room deserted—pupils will naturally go to the equally good teacher who gives more teaching for the same fee, or the same teaching for a less cost. And no one can say that this is not as it should be. The university pupil requires a certain course of instruction, which he ought to be able to buy at the cheapest rate. It does not seem to be doing justice to the pupil to compel him to form one of a class consisting of some hundreds of hearers, where he can obtain but little personal supervision or attention from the teacher, whereas if he had the free disposal of his fee, he might obtain six times the amount of attention from another teacher. This arrangement does not seem to be justifiable, even for the purpose of providing the university professor with an income and leisure to pursue scientific research. The student's fee should pay for a given amount of teaching at the market value, and he has just cause of complaint if, by compulsory enactments, he is taxed to provide the country with scientific investigation.

Teaching must, in all fairness, ultimately be paid for as teaching, and scientific research must be provided for out of other funds than those extracted from the pockets of needy students, who have a reasonable right to demand, in return for their fees, a full modicum of instruction and direction in study.

In the German universities, the professor receives a stipend which provides for him as an investigator. He also gives lectures, for which he charges a fee, but no student is compelled to attend those lectures as a condition of obtaining his degree. Accordingly, independent teachers can, and do, compete with the professor in providing for the students' requirements in the matter of instruction. As a consequence, the fees charged for teaching are exceedingly small, and the student can feel assured that he is obtaining his money's worth for his money. He is not compelled to pay any fee to any teacher as a condition of his promotion to the university degree. In a German university, if the professor in a given subject is incompetent, or the class overcrowded, the student can take his fee to a private teacher, and get

better teaching; all that is required of the candidate, as a condition of his promotion to the Doctor's degree, is that he shall satisfy the examination-tests imposed by the faculty, and produce an original thesis.

Unless there be some such compelling influence as that obtaining in the Scotch universities, enabling the would-be researcher to gather to him pupils and fees without fear of competition, it seems impossible that he should gain an income by teaching whilst reserving to himself time and energy for the pursuit of scientific inquiry. It is thus seen that the necessity of endowment, in some form or another, to make provision for scientific research, is a reality, in spite of the suggestion that teaching affords a means whereby the researcher may readily provide for himself. The simple fact is that a teacher can only make a sufficient income by teaching, on the condition that he devotes his whole time and energy to that occupation.

Whilst I feel called upon to emphatically distinguish the two functions—viz., that of *creating new knowledge*, and that of *distributing existing knowledge*—and to maintain that it is only by arbitrary and undesirable arrangements, not likely to be tolerated, or, at any rate, extended, at the present day, that the latter can be made to serve as the support of the former, I must be careful to point out that I agree most cordially with those who hold that it is an excellent thing for a man who is engaged in the one to give a certain amount of time to the other. It is a matter of experience that the best teachers of a subject are, *ceteris paribus*, those who are actually engaged in the advancement of that subject, and who have shown such a thorough understanding of that subject as is necessary for making new knowledge in connection with it. It is also, in most cases, a good thing for the man engaged in research to have a certain small amount of change of occupation, and to be called upon to take such a survey of the subject in connection with which his researches are made, as is involved in the delivery of a course of lectures and other details of teaching. Though it is not a thing to be contemplated that the researcher shall sell his instruction at a price sufficiently high to enable him to live by teaching, yet it is a good thing to make teaching an additional and subsidiary part of his life's work. This end is effected in Germany by making it a duty of the professor, already supported by a stipend, to give some five or six lectures a week during the academical session, for which he is paid by the fees of his hearers. The fees are low, but are sufficient to be an inducement; and, inasmuch as the attendance of the students is not compulsory, the professor is stimulated to produce good and effective lectures at a reasonable charge, so as to attract pupils who would seek instruction from some one else if the lectures were not good or the fees too high. Indeed, in Germany this system works so much to the advantage of the students, that the private teachers of the universities at one time obtained the creation of a regulation forbidding the professors to reduce their fees below a certain minimum, since, with so low a fee as some professors were charging, it was impossible for a private teacher to compete! This state of things may be compared, with much advantage, with the condition of British universities. In these we hear, from one direction, complaints of the high fees charged and of the ineffective teaching given by the professoriate; and in other universities, where no adequate fees are allowed to the professors as a stimulus to them to offer useful and efficient teaching, we find that the teaching has passed entirely out of their hands into those of college tutors and lecturers. The fact is that a satisfactory relation between teaching and research is one which will not naturally and spontaneously arrange itself. It can hardly be said to exist in any British university or college, but the method has been thought out and carried into practice in Germany. It consists in giving a competent researcher a stipend and a laboratory for his research work, and then requiring him to do a small amount of teaching, remunerated by fees proportionate to his ability and the pains which he may take in his teaching. If you pay him a fixed sum as a teacher, or artificially insure the attendance of his class, instead of letting this part of his income vary simply and directly with the attractiveness of his teaching, you will find as the result that (with rare exceptions) he will not give effective and useful teaching. He will naturally tend to do the minimum required of him, in a perfunctory way. On the other hand, if you leave him without stipend as a researcher, dependent on the fees of pupils for an income, he will give all

his time and energies to teaching, he will cease to do any research, and become, *pro tanto*, an inferior teacher.

A third objection which is sometimes made to the proposition that scientific research must be supported and paid for as such, is the following: It is believed by many persons that a man who occupies his best energies in scientific research can always, if he choose, make an income by writing popular books or newspaper articles in his spare hours; and, accordingly, it is gravely maintained that there is no need to provide stipends and the means of carrying on their work for researchers. To do so, according to this view, would be to encourage them in an exclusive reticence, and to remove from them the inducement to address the public on the subject of their researches, by which the public would lose valuable instruction.

This view has been seriously urged, or I should not here notice it. Anyone who is acquainted with the sale of scientific books, and the profits which either author or publisher makes by them, knows that the suggestion which I have quoted is ludicrous. The writing of a good book is not a thing to be done in leisure moments, and such as have been the result of original research have cost their authors often years of labour apart from the mere writing. Mr. Darwin's books, no doubt, have had a large sale; but that is due to the fact, apart from the exceptional genius of the man who wrote them, that they represent some thirty or more years of hard work, during which he was silent. There is not a sufficiently large public interested in the progress of science to enable a researcher to gain an income by writing books, however great his literary facility. A school-book or class-book may now and then add more or less to the income of a scientific investigator; but he who becomes the popular exponent of scientific ideas, except in a very moderate and limited degree, must abandon the work of creating new knowledge. The professional *littérateur* of science is as much removed by his occupation from all opportunity of serious investigation as is the professional teacher who has to consume all his time in teaching. Any other profession—such as the Bar, Medicine, or the Church—is more likely to leave one of its followers time and means for scientific research than is that of either the popular writer or the successful teacher.

We have, then, seen that there is no escape from the necessity of providing stipends and laboratories for the purpose of creating new knowledge, as is done in continental States, if we are agreed that more of this new knowledge is needed and is among the products which a civilised community is bound to turn out, both for its own benefit and for that of the community of States, which give to and take from one another in such matters.

There are some who would finally attack our contention by denying that new knowledge is a good thing, and by refusing to recognise any obligation on the part of England to contribute her share to that common stock of increasing knowledge by which she necessarily profits. Among such persons are those who would prohibit altogether the pursuit of experimental physiology in England, and yet would not and do not hesitate to avail themselves of the services of medical men, whose power of rendering those services depends on the fact that they have learnt the results obtained by the experiments of physiologists in other countries or in former times. In reference to this strange contempt and even hatred of science, which undoubtedly has an existence among some persons of consideration, even at the present day, I shall have a few words to say before concluding this address. I have now to ask you to listen to what seems to me to be the demand which we should make, as members of a British Association for the Advancement of Science, in respect of adequate provision for the creation of new knowledge in the field of biology in England.

Taking England alone, as distinct from Scotland and Ireland, we require, in order to be approximately on a level with Germany, forty new biological institutes, distributed among the five branches of physiology, zoology, anatomy, pathology, and botany—forty in addition to the fifteen which we may reckon (taking one place with another) as already existing. The average cost of the buildings required would be about 4,000*l.* for each, giving a total initial expenditure of 160,000*l.*; the average cost of stipends for the director, assistants, and

maintenance we may calculate at 1,500*l.* annually for each, or 60,000*l.* for the forty—equal to a capital sum of 2,000,000*l.* These institutes should be distributed in groups of five—eight groups in all—throughout the country. One such group would be placed in London (which is, at present, almost totally destitute of such arrangements), one in Bristol, one in Birmingham, one in Nottingham, one in Leeds, one in Newcastle, one in Ipswich, one in Cardiff, one in Plymouth—in fact, one in each of the great towns of the kingdom where there is at present, or where there might be with advantage, a centre of professional education and higher study. The first and the most liberally arranged of these biological institutes—embracing its five branches, each with its special laboratory and staff—should be in London. If we can have nothing else, surely we may demand, with some hope that our request will eventually obtain compliance, the formation in London of a College of Scientific Research similar to that of Paris (the Collège de France). It is one of the misfortunes and disgraces of London that—alone amongst the capitals of Europe, with the exception of Constantinople—it is destitute of any institution corresponding to the universities and colleges of research which exist elsewhere.

Either in connection with a properly organised teaching university or as an independent institution, it seems to me a primary need of the day that the Government should establish in London laboratories for scientific research. Two hundred and fifty years ago Sir Thomas Gresham founded an institution for scientific research in the City of London. The property which he left for this purpose is now estimated to be worth three millions sterling. This property was deliberately appropriated to other uses by the Corporation of the City of London and the Mercers' Company about a hundred years since, with the consent of both Houses of Parliament. By this outrageous act of spoliation these Corporations, who were the trustees of Gresham, have incurred the curse which he quaintly inserted in his will in the hope of restraining them from attempts to divert his property from the uses to which he destined it. 'Gresham's curse' runs as follows:—'And that I do require and charge the said Corporations and chief governors thereof, with circumspect Diligence and without long Delay, to procure and see to be done and obtained, as they will answer the same before Almighty God; (for if they or any of them should neglect the obtaining of such Licenses or Warrants, which I trust can not be difficult, nor so chargeable, but that the overplus of my Rents and Profits of the Premisses hereinbefore to them disposed, will soon recompense the same; because to soe good Purpose in the Commonwealth, no Prince ncr Council in any Age, will deny or defeat the same. And if conveniently by my Will or other Convenience, I might assure it, I would not leave it to be done after my death, then the same shall revert to my heirs, whereas I do mean the same to the Commonwealth, and then THE DEFAULT THEREOF SHALL BE TO THE REPROACH AND CONDEMNATION OF THE SAID CORPORATIONS AFORE GOD'). I confess that I find it difficult to see how the present representatives of the Corporations who perverted Gresham's trust are to escape from justly deserving the curse pronounced against those Corporations, unless they conscientiously take steps to restore Gresham's money to its proper uses. Let us hope that Gresham's curse may be realised in no more deadly form than that of an Act of Parliament repealing the former one which sanctioned the perversion of Gresham's money. Such a sequel to the Report of the Commission which has recently inquired into the proceedings of the Corporation and Companies of the City of London is not unlikely.

Whilst we should, I think, especially press upon public attention the need for an institute of scientific research in London, and indicate the source from which its funds may be fitly derived, we must also urge the foundation of other institutes in the provinces upon the scale already sketched, because it is only by the existence of numerous posts, and of a series of such posts—some of greater and some of less value, the latter more numerous than the former—that anything like a professional career for scientific workers can be constructed. It is especially necessary to constitute what I have termed 'assistantships,' that is, junior posts in which younger men assist and are trained by more experienced men. Even in the few institutions which do already exist additional provision of this kind is what is wanted more than anything else, so that there may be a progressive career open

to the young student, and a sufficient field of trained investigators from which to select in filling up the vacancies in more valuable positions.

I am well aware that it will be said that the scheme which I have proposed to you is gigantic and almost alarming in respect of the amount of money which it demands. One hundred and sixty thousand pounds a year for biology alone must seem, not to my hearers, but to those who regard biology as an amusing speculation—that is to say, who know little or nothing about it—an extravagant suggestion. Unfortunately it is also true that such persons are very numerous—in fact, constitute an overwhelming majority of the community; but they are becoming less numerous every day. The time will come, it seems possible, when there will be more than one member of the Government who will understand and appreciate the value of scientific research. There are already a few members of the House of Commons who are fully alive to its significance and importance.

We may have to wait for the expenditure of such a sum as I have named, and possibly it may be derived ultimately from local rather than imperial sources, though I do not see why it should be; yet I think it is a good thing to realise *now* that this is what we ought to expend in order to be on a level with Germany. This apparently extravagant and unheard of appropriation of public money *is actually made every year in Germany.*

I think it is well to put the matter before you in this definite manner, because I have reason to believe that even those whom we might expect to be well-informed in regard to such matters, are not so, and as a consequence there is not that keen sense of the inferiority and inadequacy of English arrangements in these matters which one would gladly see actuating the conduct of English statesmen. For instance, only a few years ago, when speaking at Nottingham, the present Prime Minister, who has taken an active part in rearranging our universities, and has, it is well known, much interest in science and learning, stated that 27,000*l.*, the capital sum expended on the Nottingham College of Science, was a very important contribution to the support of learning in this country, amounting, as he said he was able to state, from the perusal of official documents, to as much as one-third of what was spent in Germany during the past year upon her numerous universities, which were so often held up to England as an example of a well-supported academical system. Now, I do not think that Mr. Gladstone can have ever had the opportunity of considering the actual facts with regard to German universities, for he was in this instance misled by the official return of expenditure on a single university, namely, that of Strasburg; the total annual expenditure on the twenty-one German universities being, in reality, about 800,000*l.*, by the side of which a capital sum of 27,000*l.* looks very small indeed. I cannot but believe that if the facts were known to public men, in reference to the expenditure incurred by foreign States in support of scientific inquiry, they would be willing to do something in this country of a sufficient and statesmanlike character. As it is, the concessions which have been made in this direction appear to me to be in some instances not based upon a really comprehensive knowledge of the situation. Thus, the tentative grant of 4,000*l.* a year from the Treasury to the Royal Society of London appears to me not to be a well-devised experiment in the promotion of scientific research by means of grants of money, because it is on too small a scale to produce any definite effect, and because the money cannot be relied upon from year to year as a permanent source of support to any serious undertaking.

The Royal Society most laboriously and conscientiously does its best to use this money to the satisfaction of the country, but the task thus assigned to it is one of almost insurmountable difficulty. In fact, no such miniature experiments are needed. The experiment has been made on a large scale in Germany, and satisfactory results have been obtained. The reasonable course to pursue is to benefit by the experience, as to details and methods of administration, obtained in the course of the last sixty years in Germany, and to apply that experience to our own case.

It is quite clear that 'the voluntary principle' can do little towards the adequate endowment of scientific research. Ancient endowments belonging to the country must be applied thereto, or else local or imperial taxes must be the source

of the necessary support. Seeing that the results of research are distinctly of imperial, and not of local value—it would seem appropriate that a portion of the imperial revenue should be devoted to their achievement. In fact, as I have before mentioned, the principle of such an application of public money has long been admitted, and is in operation.

Whilst voluntary donations on the part of private persons can do little to constitute a fund which shall provide the requisite endowment for the scheme of biological institutes which I have sketched (not to mention those required for other branches of science), yet those who are interested in the progress of scientific investigation may by individual effort do something, however little, towards placing research in a more advantageous position in this country. Supposing it were possible, as I am sanguine enough to believe that it is, to collect in the course of a year or two from private sources a sum of 20,000*l.* for the maintenance of a biological laboratory and staff, it would be necessary, in expending so limited a sum, to aim at the provision of something which would be likely to produce the largest and most obvious results in return for the outlay, and to benefit the largest number of scientific observers in this department.

I believe that it is the general opinion among biologists that there could be no more generally useful institution thus set in operation than a biological laboratory upon the sea-coast, which, besides its own permanent staff of officers, would throw open its resources to such naturalists as might from time to time be able to devote themselves to researches within its precincts. There is no such laboratory on the whole of the long line of British coast. At Naples there is Dr. Dohrn's celebrated and invaluable laboratory, which is frequented by naturalists from all parts of the world; at Trieste the Austrian Government supports such a laboratory; at Concarneau, Roscoff, and Villefranche, the French Government has such institutions; at Beaufort, in North Carolina, the Johns Hopkins University has its marine laboratory; and at Newport, Professor Alexander Agassiz has arranged a very perfect institution also for the study of marine life. In spite of the great interest which English naturalists have always taken in the exploration of the sea and marine organisms—in spite of the fact that the success and even the existence of our fisheries-industries to a large extent depends upon our gaining the knowledge which a well-organised laboratory of marine biology would help us to gain, there is actually no such institution in existence.

This is not the occasion on which to explain precisely how and to what extent a laboratory of marine zoology might be of national importance. I hope to see that matter brought before the Section during the course of our meeting. But I may point out now, that though it appears to me that the great need for biological institutes, to which I have drawn your attention, can *not* be met by private munificence, and must in the end be arranged for by the continued action of the Government in carrying out a policy to which it has for many years been committed, and which has been approved by Conservatives and Liberals alike—yet such a special institution as a laboratory of marine biology, serving as a temporary workshop to any and all of our numerous students of the important problems connected with the life of marine plants and animals, might very well be undertaken from private funds. Should it be possible, on the occasion of this meeting of the British Association in Southport, to obtain some promise of assistance towards the realisation of this project, I think we shall be able to congratulate ourselves on having done something, though small perhaps in amount, towards making better provision for biological research, and therefore something towards the advancement of science.

In conclusion, let me say that, in advocating to-day the claim of biological science to a far greater measure of support than it receives at present from the public funds, I have endeavoured to press that claim chiefly on the ground of the obvious utility to the community of that kind of knowledge which is called biology. I have endeavoured to meet the opposition of those who object to the interference of the State wherever it may be possible to attain the end in view without such interference, but who profess themselves willing to see public money expended in promoting objects which are of real importance to the country, and

which cannot be trusted to the voluntary enterprise arising from the operation of the laws of self-preservation and the struggle for wealth. There are, however, it seems to me, further reasons for desiring a thorough and practical recognition by the State of the value of scientific research. There are not wanting persons of some cultivation who have perceived and fully realised the value of that knowledge which is called science, and of its methods, and yet are anxious to restrain rather than to aid the growth of that knowledge. They find in science something inimical to their own interests, and accordingly either condemn it as dangerous and untrustworthy, or encourage themselves to treat it with contempt by asserting that 'after all, science counts for very little'—a statement which is unhappily true in one sense, though totally untrue when it is intended to signify that the progress of science is not a matter which profoundly influences every factor in the well-being of the community. Amongst such people there is a positive hatred of science, which finds expression in their exclusion of it, even at this day, from the ordinary curriculum of public school education, and in the baseless though oft-repeated calumny that science is hostile to art, and is responsible for all that is harsh, ugly, and repulsive in modern life. To such opponents of the advancement of science, it is of little use to offer explanations and arguments. But we may, when we reflect on their instinctive hostility and the misrepresentations of science and the scientific spirit which it leads them to disseminate, console ourselves by bringing to mind what science really is, and what truly is the nature of that calling in which a man who makes new knowledge is engaged.

They mock at the botanist as a pedant, and the zoologist as a monomaniac; they execrate the physiologist as a monster of cruelty, and brand the geologist as a blasphemer; chemistry is held responsible for the abomination of aniline dyes and the pollution of rivers, and physics for the dirt and misery of great factory towns. By these unbelievers science is declared responsible for individual eccentricities of character, as well as for the sins of the commercial utilisers of new knowledge. The pursuit of science is said to produce a dearth of imagination, incapability of enjoying the beauty either of nature or of art, scorn of literary culture, arrogance, irreverence, vanity, and the ambition of personal glorification.

Such are the charges from time to time made by those who dislike science, and for such reasons they would withhold, and persuade others to withhold, the fair measure of support for scientific research which this country owes to the community of civilised states. Not in reply to these misrepresentations, but by way of contrast, I would here state what science seems to be to those who are on the other side, and how, therefore, it seems to them wrong to delay in doing all that the wealth and power of the State can do, to promote its progress.

Science is not a name applicable to any one branch of knowledge, but includes all knowledge which is of a certain order or scale of completeness. All knowledge which is deep enough to touch the causes of things, is Science; all inquiry into the causes of things is scientific inquiry. It is not only co-extensive with the area of human knowledge, but no branch of it can advance far without reacting upon other branches; no department of Science can be neglected without sooner or later causing a check to other departments. No man can truly say this branch of Science is useful and shall be cultivated, whilst this is worthless and shall be let alone; for all are necessary, and one grows by the aid of another, and in turn furnishes methods and results assisting in the progress of that from which it lately borrowed.

We desire the increase and the support and the acceptance of Science, not only because it has a certain material value and enables men to battle with the forces of nature and to turn them to account, so as to increase both the intensity and the extension of healthy human life: that is a good reason, and for some persons, it may be, the only reason. But there is something to be said beyond this.

The pursuit of scientific discovery, the making of new knowledge, gratifies an appetite which, from whatever cause it may arise, is deeply seated in man's nature, and indeed is the most distinctive of his properties. Man owes this intense desire to know the nature of things, smothered though it often be by other cravings which he shares with the brutes, to an inherited race-perception stronger than the reasoning faculty of the individual. When once aroused and in a measure gratified, this

desire becomes a guiding passion. The instinctive tendency to search out the causes of things, gradually strengthening as generation after generation of men have stumbled and struggled in ignorance, has at last become an active and widely-extending force: it has given rise to a new faith.

To obey this instinct—that is, to aid in the production of new knowledge—is the keenest and the purest pleasure of which man is capable, greater than that derived from the exercise of his animal faculties, in proportion as man's mind is something greater and further developed than the mind of brutes. It is in itself an unmixed good, the one thing which commends itself as still 'worth while' when all other employments and delights prove themselves stale and unprofitable.

Arrogant and foolish as those men have appeared who, in times of persecution and in the midst of a contemptuous society, have, with an ardour proportioned to the prevailing neglect, pursued some special line of scientific inquiry, it is nevertheless true that in itself, apart from special social conditions, Science must develop in a community which honours and desires it before all things, qualities and characteristics which are the highest, the most human of human attributes. These are, firstly, the fearless love and unflinching acceptance of truth; hopeful patience; that true humility which is content not to know what cannot be known, yet labours and waits; love of Nature, who is not less, but more, worshipped by those who know her best; love of the human brotherhood for whom and with whom the growth of science is desired and effected.

No one can trace the limits of Science, nor the possibilities of happiness both of mind and body which it may bring in the future to mankind. Boundless though the prospect is, yet the minutest contribution to the onward growth has its absolute and unassailable value; once made it can never be lost: its effect is for ever in the history of man.

Arts perish, and the noblest works which artists give to the world. Art (though the source of great and noble delights) cannot create nor perpetuate; it embodies only that which already exists in human experience, whilst the results of its highest flights are doomed to decay and sterility. A vain regret, a constant effort to emulate or to imitate the past, is the fitting and laudable characteristic of Art at the present day. There is, indeed, no truth in the popular partition of human affairs between Science and Art as between two antagonistic or even comparable interests; but the contrast which they present in points such as those just mentioned is forcible. Science is essentially creative; new knowledge—the experience and understanding of things which were *previously non-existent for man's intelligence*, is its constant achievement. And these creations never perish; the new is built on and incorporates the old; there is no turning back to recover what has lapsed through age; the oldest discovery is even fresher than the new, yielding in ever increasing number new results, in which it is itself reproduced and perpetuated, as the parent in the child.

This, then, is the faith which has taken shape in proportion as the innate desire of man for more knowledge has asserted itself—namely, that there is no greater good than the increase of Science; that through it all other good will follow. Good as Science is in itself, the desire and search for it is even better, raising men above vile things and worthless competitions to a fuller life and keener enjoyments. Through it we believe that man will be saved from misery and degradation, not merely acquiring new material powers, but learning to use and to guide his life with understanding. Through Science he will be freed from the fetters of superstition; through faith in Science he will acquire a new and enduring delight in the exercise of his capacities: he will gain a zest and interest in life such as the present phase of culture fails to supply.

In opposition to the view that the pursuit of Science can obtain a strong hold upon human life, it may be argued, that on no reasonable ground can it appear a necessary or advantageous thing to the individual man to concern himself with the growth and progress of that which is merely likely to benefit the distant posterity of the human race. Our reply is: Let those who contend for the reasonableness of human motives develop, if they can, any theory of human conduct in which

reasonable self-interest shall be man's guide. We do not contend for any such theory. By reasoning we may explain and trace the development of human nature, but we cannot change it by any such process. It is demonstrably unreasonable for the individual man, guided by self-interest, to share the dangers and privations of his brother-man, and yet, in common with many lower animals, he has an inherited quality which makes it a pleasure to him to do so; it is unreasonable for the mother to protect her offspring, and yet it is the natural and inherited quality of mothers to derive pleasure from doing so; it is unreasonable for the half-starved poor to aid their wholly starving brethren, and yet such compassion is natural and pleasurable to those who show it, and is the constant rule of life. Unreasonable though these things are from the point of view of individual self-interest, yet they are done because to do them is pleasurable, to leave them undone a pain. The race has, as it were, in these respects befooled the individual, and in the course of evolution has planted in him, in its own interests, an irrational capacity for taking pleasure in doing that which no reasoning in regard to self-interest could justify. As with these lower and more widely distributed instincts, shared by man with some lower social animals, so is it with this higher and more peculiar instinct—the tendency to pursue new knowledge. Whether reasonable or not, it has by the laws of heredity and selection become part of us and exists: its operation is beneficial to the race: its gratification is a source of keen pleasure to the individual—an end in itself. We may safely count upon it as a factor in human nature; it is in our power to cultivate and develop it, or, on the other hand, to starve and distort it for a while, though to do so is to waste time in opposing the irresistible.

As day by day the old-fashioned stimulus to the higher life loses the dread control which it once exercised over the thoughts of men, the pursuit of wealth and the indulgence in fruitless gratifications of sense become to an increasing number the chief concerns of their mental life. Such occupations fail to satisfy the deep desires of humanity; they become wearisome and meaningless, so that we hear men questioning whether life be worth living. When the dreams and aspirations of the youthful world have lost their old significance and their strong power to raise men's lives, it will be well for that community which has organised in time a following of and a reverence for an ideal Good, which may serve to lift the national mind above the level of sensuality and to ensure a belief in the hopefulness and worth of life. The faith in Science can fill this place—the progress of Science is an ideal Good, sufficient to exert this great influence.

It is for this reason more than any other, as it seems to those who hold this faith, that the progress and diffusion of scientific research, its encouragement and reverential nurture, should be a chief business of the community, whether collectively or individually, at the present day.

The following Papers were read:—

1. *On the Origin and Development of the Rhinoceros Group.* *By* W. B. Scott *and* H. F. Osborne.

The oldest known member of this line is the genus *Orthocynodon* (Scott and Osborne), from the lower strata of the great Bridger basin of Wyoming, belonging to the Middle Eocene of America, which is very rich in perissodactyl types. Among these the *Lophiodontidæ* occupy a prominent position; they are probably the ancestors of both rhinoceros and tapir, and *Orthocynodon* may be characterised as a lophiodont with rhinoceros-like molars. The authors proceed to review the relative positions of *Aceratherium, Diceratherium,* and *Hyracodon.*

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2. *On the Differences between the Males and Females of the Pearly Nautilus.*[1] *By* A. G. Bourne.

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[1] Published in the *Transactions of the Zoological Society.*

3. *On the Polymorphism of Alcyonaria.* *By* Professor MILNES MARSHALL, *M.D.*, *D.Sc.*

Among the specimens of Pennatulida dredged by H.M.S. 'Triton' in the Faroe Channel during last autumn were two cases in which the asexual zooids present features of special interest.

In the first case, the variety of *Pennatula phosphorea* known as *aculeata,* certain of the zooids along the ventral surface are much enlarged and assume the form of conical spikes, which attain a length of nearly a quarter of an inch. The greater part of the length of the spike is formed by a unilateral development of the calyx containing prolongations of the body cavity, the mouth of the zooid being situated near the base of the spike.

In the second case, a new species of *Umbellula,* certain of the zooids possess a single well-developed tentacle, with a row of pinnules along each side. In possessing pinnules, and thereby exactly agreeing with a tentacle of a polyp the zooids of *Umbellula gracilis* are unique, and a very interesting question arises as to whether this unitentacular condition is to be considered primitive or not. This question was discussed at some length, the evidence we possess, which however is avowedly very defective, being on the whole rather against its primitive nature.[1]

4. *On the Budding of Polyzoa.* *By* Professor A. C. HADDON.

FRIDAY, SEPTEMBER 21.

The following Reports and Papers were read:—

1. *Third Report of the Committee for the Investigation of the Natural History of Timor-laut.*—See Reports, p. 224.

2. *Report of the Committee for the Investigation of the Natural History of Socotra and the adjacent Highlands of Arabia and Somali Land.* See Reports, p. 227.

3. *Report of the Committee for the Exploration of Kilimanjaro and the adjoining Mountains of Eastern Equatorial Africa.*—See Reports, p. 228.

4. *Report on the Migration of Birds.*—See Reports, p. 229.

5. *On a young specimen of the Grey Seal (H. gryphon) from Boscastle, Cornwall.* *By* Professor E. RAY LANKESTER, *F.R.S.*

This recently-born animal was found on the rocks, and brought up alive and deposited in the gardens of the Zoological Society of London. It is believed that the locality is the most southern on record for the breeding of this species.

6. *On the Germ-Theory of Disease, considered from the Natural History point of view.* *By* WILLIAM B. CARPENTER, *C.B.*, *F.R.S.*

The object of this paper is to bring together two orders of facts, of whose bearing on one another (in the author's opinion) too little account has hitherto been

[1] For full description of these forms *vide* 'Report on the Pennatulida dredged by H.M.S. *Triton*.'—*Trans.* Roy. Soc. Edin. 1883.

taken—those which demonstrate the polymorphism of the lowest forms of animal and vegetable life to which the Schizomycetes are most nearly related, and those which indicate the polymorphism of Diseases accounted 'specific' by the pathologist. In the pre-Darwinian days in which every species of plant or animal was regarded as a special creation, permanently transmitting its distinctive peculiarities from parent to offspring, there were two schools of botanists and zoologists: one laying the greatest stress on minute differences, and multiplying species to an extravagant extent; while the other, looking rather to points of agreement, to the gradational characters presented by the differences when the comparison is made between a sufficiently large number of forms collected from a wide area of distribution, and to the modifying influence of external conditions, aimed to reduce the number of specific types by making a large allowance for 'range of variation.' Among the flowering plants of Britain, for example, nearly 1,700 species were enumerated by one distinguished botanist; while another reduced the number below 1,200—chiefly by the suppression (on the foregoing grounds) of the large number of species contained in the variable genera *Rosa*, *Rubus*, and *Salix*. And whilst D'Orbigny, in his classification of *Foraminifera*, enormously multiplied Genera as well as Species, by selecting only the most strongly differentiated types, later systematists, by tracing out the gradational connections between these, have greatly reduced their number.

The Evolutionist who looks at species simply as races, which, *having come to be* differentiated from each other, transmit their respective differentiæ by genetic descent, is prepared to admit any amount of such gradation; the supposed permanence of specific types being, in his view, simply the result of persistence of the same external conditions, and giving place to change of type whenever these conditions undergo any essential modification. The well-informed botanist or zoologist, then, no longer entertains the idea of fixity in natural species; and specific designations are now only used provisionally, as indicating races in which well-marked differential characters have been found to be transmitted genetically so long as our term of observation has lasted. To the amount of change in any race which might take place under the influence of small variations in external conditions, acting persistently through a long succession of generations, no scientific Naturalist would now feel justified in assigning limits.

The author desires to lay special stress upon two orders of facts, which he believes to be familiar to every experienced naturalist. It not unfrequently happens, in the first place, that two types of plants or animals present in one locality very well marked differential characters, and transmit these with such genetic continuity as apparently to justify the ranking them as distinct species; while yet, in some other locality, they are found to be connected by such a gradational series of intermediate forms that it is impossible to draw a definite line of demarcation between them. And, secondly, range of variation, arising out of the modifying influence of external conditions, shows itself more strongly in the lower than in the higher forms of vegetable and animal life; and in no group more strongly than in the simplest Fungi (the 'moulds' and 'blights') to which the Schizomycetous 'disease-germs' are most nearly related. From the natural-history point of view, therefore, we should expect that instead of always developing themselves in one particular mode, and giving rise, by their introduction into the human body, to one fixed and constant type of morbid action, those different forms of bacilli, bacteria, or micrococci, which we are now learning to regard as the germs of the different species of zymotic disease recognised by the Pathologist, should be capable of undergoing considerable modification according to the conditions under which they are developed, especially when those conditions act persistently through a succession of generations. And we should further expect that, as the diseases which we now regard as specifically distinct *have come to be* so by a process of evolution, so, notwithstanding the well-marked differentiæ which they may usually present, they may in other localities or at other times graduate insensibly into each other—a mild disease-germ developing itself into a virulent one, or, conversely, a very severe type of disease showing itself under an extremely mitigated form. Now this is precisely what the culture-experiments of Pasteur and his followers have

proved to be the fact; the potency of certain disease-germs which have been made the subject of special research being now found to be capable of a regulation almost as precise as the precipitating power of the solution of a chemical reagent.

Notwithstanding the tendency among modern Pathologists to regard the various forms of Zymotic disease as specifically distinct, and to attribute to inexact observation every recorded fact which runs counter to their preconceptions, the Author holds that the application of the natural-history method to the study of these diseases fully justifies the belief, that the same germs, undergoing development under different conditions, may manifest themselves under a great variety of forms; and maintains that a larger study of the history of medicine also justifies the belief that while some of these forms (such as the Exanthemata) have acquired a considerable fixity, breeding only in the human body, yet that this fixity does not necessarily hold good over the whole world, or through all time; and that there is a large class, including Cholera and the various forms of Fever, originating in germs which breed in the soil as well as in the human body, over which the nature of the breeding-ground, with various atmospheric (possibly electrical) conditions, exerts a most important modifying influence. And he holds that this inclusive study, taking account of all the facts which science can bring to bear on the inquiry, is much more likely to lead to accurate results, than the exclusive method followed by most Pathologists.

In regard to Cholera in particular, he regarded it as still an open question whether this disease is as specifically distinct from all others as it is commonly regarded. Though it has been customary to represent true cholera as having always radiated from India (which country never seems entirely free from it), yet the author distinctly recollects the occurrence at Clapham of what was recognised by an old Indian practitioner as Asiatic cholera, some years before the first epidemic visitation of 1832. And the report recently made by Surgeon-General Hunter on the epidemic of cholera now prevailing in Egypt, attributes its origin to local conditions, which have produced an increasingly severe type of choleraic diarrhœa, at last developing true cholera. This entirely accords with the view that disease-germs which might originally have only produced a mild form of choleraic disease, may be so 'cultivated' as to develope its most malignant type. The author illustrated this by the example of Small-pox, which he regarded as having been greatly mitigated during the last century by the beneficial 'cultivation' of its milder variety by Inoculation; while the germs of the same disease, developing themselves during the siege of Paris in the blood of men already rendered unhealthy by unfavourable conditions, produced a malignant form of the disease, which had never before prevailed epidemically during the present century, but which has been during the last twelve years the principal source of its fatality.

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7. *On Wool Plugs and Sterilised Fluids.* By J. Duncan Matthews, *F.R.S.E.*

The paper described in detail a series of experiments made with the purpose of testing how far wool plugs were to be relied on as filters of atmospheric air, and, consequently, as preventers of the putrefaction of sterilised fluids protected thereby from contamination of germs in the air.

Flasks containing various cultivating fluids (5 per cent. Liebig's extract being generally employed) were filtered into and boiled in glass flasks of about 4 oz. capacity, closed by one or more plugs of cotton wool, or salicylic wool, or wool which had been steeped for some time in 5 per cent. carbolic acid and water, and often had in addition a sheet of salicylic wool placed over the plug and tied down beneath the lip of the flask. The flasks were previously washed out with nitric, sulphuric, or carbolic acids, and then with water, and often were subjected thereafter to a temperature of 400° Fahr. Boiled for fifteen minutes, allowed to cool, and then placed in an incubator at a temperature of 100° Fahr., the contained fluids—prepared in various laboratories, the air of which was known to be highly

charged with germs—always putrefied in from eighteen to thirty hours, or, if left at the ordinary temperature of the air, at various periods of from four days to three weeks, becoming opaque, muddy, and forming a scum—generally of *bacilli*, but often of *bacterium termo*. It was found, if the laboratory was cleaned out and allowed to remain undisturbed for a week or two, that for some days fluids prepared in this way were perfectly and permanently sterilised, but after the accumulation and raising of dust by work carried on there, they invariably broke down. Fluids prepared in flasks with necks finely drawn out and hermetically closed by fusing the glass during boiling invariably remained pure. This did not seem necessarily to be due to want of air in the flask, for hay *bacillus* developed under these conditions when a few hay stalks were inclosed in the flask before boiling, the hay *bacillus* germs resisting the action of a boiling temperature for some time if protected by the hay fibres. But if the tip of these hermetically closed flasks was broken off, and the air allowed free entrance, though for so short a period as three seconds, putrefaction resulted. But the fact that the putrefaction did not arise from germs originally present in the cultivating fluids or in the flasks, or, being present there, from their withstanding the action of a boiling temperature, was more conclusively proved by preparing in flasks with necks about $\frac{1}{4}$ inch diameter, bent downwards, so that, after boiling, the flame of a spirit lamp might be placed under the mouth, and allowed to burn around and *up* the neck for about 1 inch, while the flask cooled. In such cases (a small wool plug being afterwards inserted in the mouth), or if the neck was bent up and down several times and simply left open, the fluid invariably remained pure in the incubator for any length of time. The wool was not likely to be at fault, for, besides its being carbolised, if the necks thus bent down were plugged in the ordinary way, the inrushing air not being calcined, the fluids in them also putrefied, though it was probable that any germs present in the wool, and not killed by being steamed, could not fall into the fluid.

Professor Tyndall's plan of discontinuous boiling was employed, the fluids being boiled three to nine times at intervals of twelve hours, but with no better result than in the ordinary cases, putrefaction occurring about twenty hours after the last boiling. If water is sprayed, or a little poured over the wool-plugged flask during cooling, the strong indraught of air to fill the vacuum caused by the boiling draws in the fluid especially quickly between the compressed plug and the sides of the flask's neck. It was proved that germs in this fluid could enter with it, and, if so, why not germs in the air?

Of six flasks, however, prepared in a pure atmosphere and perfectly sterilised, three only, on reboiling in a contaminated atmosphere, became foul.

The author thinks his observations throw some doubt on the sufficiency of wool plugs as filtering agents where a strong current of air is passing through them, as to fill a vacuum in flasks, though they seem to be perfectly reliable in cases of ordinary slight and slow changes of temperature, but he thinks further observations necessary to finally settle the point.

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8. *On Cattle Disease in South America. By* Dr. Roy.

SATURDAY, SEPTEMBER 22.

The following Papers were read:—

1. *On the occurrence of Chlorophyll in Animals.* *By* Dr. C. A. MacMunn, *M.D.*, *B.A.*, *F.C.S.*

In determining the presence of chlorophyll in an animal observers have to rely on certain microscopic, physiological, and spectroscopic proofs, which, as Professor

Lankester has pointed[1] out, are in some cases attended with difficulty. In the instances about to be brought forward the microscopic and physiological proofs are incapable of being applied. The former has, it appears to the writer, too much importance attached to it, as chlorophyll in plants may occur evenly diffused throughout the cell, dissolved in the cell-contents.

Change to a green colour on treatment with sulphuric acid, which has been observed in cases of vegetables, is no proof of the presence of a chlorophyll-like body, as the writer has seen this reaction take place in sea-anemones, in whose bodies no chlorophyll was present.

Without accepting Sorby's or Kraus's views, the name chlorophyll is here applied to that colouring matter, or mixture of colouring matters, which can be obtained from a green leaf by means of alcohol or alcohol and ether. And the proof of the identity of animal and vegetable chlorophyll is based on the coincidence of the bands of an alcohol, ether, or chloroform solution of animal and vegetable chlorophyll respectively, as well as on the coincidence of their bands on the addition of the same reagent.

The presence of the colouring matter which the writer has named 'enterochlorophyll'[2] in the appendages of the enteron of various invertebrates was then referred to, and it was shown that it is probably synthetically built up, for the following reasons:—

(1) It can be detected in the bile and alcohol-extract of the livers of snails after they have fasted for nine months.

(2) It is as abundant in the liver, or other appendage of the enteron, of an animal feeding on flesh.

(3) Its spectrum is constant in animals feeding on vegetables which give different spectra when examined in solution.

(4) It is not accompanied by other vegetable products, such as starch or cellulose, as it ought to be if food-chlorophyll.

(5) It is present in many cases in the form of chlorophyll *as such*, not in that of decomposed chlorophyll.

With regard to the possibility of symbiosis being the cause of the presence of chlorophyll, it was shown that although in some cases, *e.g.*, liver of *Helix aspersa, Limax flavus, Arion ater*, bodies resembling unicellular algæ are present, yet the chlorophyll cannot be due to them, since alcohol fails to extract their colour. Moreover, enterochlorophyll is abundantly present when no such bodies exist, e.g. liver of *Anodonta, Mytilus, Ostræa*, &c. Besides, starch ought to be present if unicellular algæ existed in those situations, which is not the case, as no reaction can be developed with iodine even after prolonged maceration of sections of invertebrate livers (fresh frozen) in alcohol and caustic potash. In addition to observations on enterochlorophyll the writer further called attention to the fact that chlorophyll may *appear* to be present in an animal when it is really due to the chlorophyll of its food, e.g. in green larvæ, for in the latter case on removing the intestinal contents the green colour and the band in red both disappear.

But in cantharides the presence of chlorophyll can be demonstrated in various extracts of the wing-cases, and here it must be a synthetic production of the animal.

Pocklington first observed chlorophyll in cantharides in 1873, and the writer has further extended his observations. It can be shown that solutions of chlorophyll obtained by digesting the above-mentioned and other parts of the bodies of these beetles in ether, alcohol, and chloroform give the same absorption bands as similar solutions of vegetable chlorophyll, and the bands are altered in the same manner as those of a similar solution of vegetable chlorophyll, on adding the same reagent, e.g. nitric acid. Here at all events we have an example of the occurrence of chlorophyll in an animal where it cannot be due directly to the food, and certainly is not due to symbiosis.

With regard to functions, chlorophyll cannot be of much use in respiration,

[1] *Quarterly Journal of Microscopical Science*, vol. xxii. p. 229.

[2] *Proceedings of the Royal Society*, No. 226, 1883.

since oxidising and reducing agents have no effect upon it; nor is it likely that it can be of any use in decomposing carbon dioxide in the absence of sunlight, buried deeply in the body of an animal, as in the case of enterochlorophyll. Its formation under these circumstances might be doubted, if we did not know that in the coniferæ and in ferns chlorophyll is formed in the dark.

On the surface of an animal it may be of use in absorbing the chemically active rays of the spectrum, as Lommel maintains in the case of vegetable chlorophyll; and C. Timiriazeff ('Compt. rend.' xcvi., 375–376) shows that Langley's measurements with the bolometer prove that the point of maximum solar energy corresponds with the principal chlorophyll band between B and C. If, however, Pringsheim's 'screen' theory be correct, this view cannot be held. It may be of use for protective purposes or in mimicry, although probably a pigment of less complicated chemical constitution might answer equally well, except that the eyes of some invertebrates may be more susceptible to rays of a certain wave-length than ours are, as Sir John Lubbock has shown to be the case in ants.

Again chlorophyll in an animal may be merely the *persistence* of a colouring matter which was useful in a remote ancestor, at a time, perhaps, when the atmosphere contained more carbon dioxide than it does now. The fact that all flowers were at one time green, may help to throw light on this point.

Enterochlorophyll may be of use in furnishing the material for the construction of chromogens or radicals for the formation of other colouring matters.

Thus the colouring matter of ox and sheep-bile appears to have some of the characters of chlorophyll, although the writer has shown that it is a hæmoglobin derivative.

Then again the elementary composition of chlorophyll and bilirubin are almost the same according to Gautier and Hoppe-Seyler; and chlorophyll and reduced hæmatin exist side by side in the bile of pulmonate mollusks, and in that of the crayfish.

The occurrence of chlorophyll in an animal should not excite so much surprise when we know that the same proteids, the same glucosides, carbohydrates, and digestive ferments are found in both kingdoms of nature. Lutein too occurs in plants and animals, and the writer has lately found tetronerythrin in an orange flower.

Those who maintain that chlorophyll does not exist in animals, evidently confound other bodies with it, such as protoplasm; and there is no doubt that chlorophyll is present in animals, being synthetically built up by and in their bodies.

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2. *On the continuity of the Protoplasm through the Walls of Vegetable cells. By* WALTER GARDINER, *B.A.*

Although the great probability of a means of communication existing between vegetable cells had been repeatedly expressed by botanists, actual demonstrable instances that such was the case were but few, being in fact limited to Sach's discovery with regard to sieve-tubes, and to the results obtained by Tangl with certain ripe endosperms.

The author, after briefly reviewing what work had been done on the subject, goes on to describe in detail his own experiments with Mimosa, Robinia, Dionœa, and other sensitive plants, and with thickened endosperm cells in general. As the results depend in a great measure upon the methods employed, he describes the various reagents he was led to make use of, the modifications adopted, and the results obtained.

In all the organs of movement examined the freely pitted parenchymatous cells were found to communicate with one another by means of delicate protoplasmic threads which perforated the closing membrane of the pits.

In order to investigate instances where the thickness of the pit membrane would allow any threads passing across it to be easily seen, the endosperm cells of some fifty species of palms, together with typical representatives of some thirteen orders, were examined, in all of which it was ascertained that definite and well-pronounced continuity existed.

Finally the author remarks that the existence of a communication between adjacent cells appears to be of very wide, if not of universal occurrence, and he briefly touches upon the important bearings this discovery has upon the cells of sensitive organs, and upon cell mechanism in general.

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3. *On the relations of Protoplasm and Cell-wall in the Vegetable cell.* *By* F. O. Bower.

After tracing the history of this subject, it was concluded that it has now been demonstrated with as much certainty as is possible, by the use of micro-chemical and staining reagents, that in certain cases, the number of which is now constantly being increased, there is a direct connection between the protoplasmic bodies on opposite sides of cell-walls, and that this connection is established by means of fine strings of protoplasm, which, in the cases observed, run nearly transversely through the walls. The question remains whether this is the *only* mode of permeation of the cell-wall by protoplasm.

The author cannot accept it as proved as yet, that any further permeation of the cell-wall by protoplasm, either as a reticulum or otherwise, really exists, but he brought forward certain grounds for regarding such a permeation as possible or even probable, taking into account chiefly those phenomena observed in *free* cell-walls, in order thereby to avoid any confusion with connecting strings, such as those already proved to exist.

1. The strings already observed vary greatly in thickness, from the well-marked to those not individually distinguishable. Thus we have evidence of the existence of strings, which would probably not have been recognised were it not for comparison with other examples. Further, it has been shown by the author's paper on plasmolysis, that protoplasm may be drawn out into strings so fine as to defy definition, even by high powers of the microscope. Thus there can be no objection on the ground of the small size of the hypothetical strings or reticulum.

2. Those cases in which perforation of cell-walls has been demonstrated, are those very cases in which a most efficient physiological connection is required; there is no reason why a less obvious permeation should be denied, where the requirements are less, but by no means absent.

3. There is *à priori* probability of some form of permeation of cell-wall by protoplasm, if Strasburger's account of the growth of cell-walls be correct.

4. A strong argument in favour of such permeation is found in the existence of important chemical changes in the substance of certain cell-walls *at points at a considerable distance from the main protoplasmic body*, e.g. formation of cuticular substance, wax, &c., which differ fundamentally from cellulose, are insoluble in water, and are apparently formed *in the wall itself*. The tendency of recent observations is to show more and more clearly how close is the connection of protoplasm with the important chemical changes in the plant; thus it appears probable that the protoplasm is present in some form or other in such cell-walls.

Reasons were also given for thinking that the exposure to air is not an important factor in the above changes.

These and other considerations show that, though this permeation of the wall cannot be accepted as proved as yet in any one case, still the subject deserves more close attention than it has yet received, while it may be expected that the application of new methods may produce definite results bearing on this very important question.

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4. *On the Intercellular Connection of Protoplasts.* *By* Professor William Hillhouse, *B.A.*, *F.L.S.*

In this paper the author commences by giving a brief summary of a paper published recently by him in the *Botanisches Centralblatt*, 'Einige Beobachtungen über den intercellularen Zusammenhang von Protoplasten,' in which he had shown that, after complete solution of the cell-wall by strong sulphuric acid, and staining

with ammonia-carmine, the separate protoplasts give evidence of various degrees of inter-relation, the most important being (1) knob-ended protoplasmic prolongations, their knobs having been firmly adherent to the middle lamella at the base of a pit ('closing membrane'), knob-ended threads from contiguous protoplasts being very commonly attached to opposite sides of the same closing membrane, and the membrane often showing cross-striation between the knobs; (2) very much less common fine unbroken threads passing from one protoplast to another, and joining them, therefore, together. These latter he had described and figured in the cortical tissue of *Ilex aquifolium* and *Æsculus hippocastanum*, the pulvinus of *Prunus Laurocerasus*, and the winter-bud pith of *Acer Pseudoplatanus*, in which alone, out of 22 plants investigated at different times and in different parts, he had found them. The author believes that most such threads would be broken in the process of preparation, but points out that rarity would be no barrier to their action, as a single thread passing from a cell to each of its impinging neighbour cells could produce a perfect unity of the vegetable organism.

Discussing the general objection formulated in the English translation of the fourth edition of Sachs' 'Lehrbuch der Botanik,' p. 788, that turgidity, and consequently the growth dependent on turgidity, would be impossible with cells having open pores in their walls, inasmuch as the smallest hydrostatic pressure of the cell sap would be equalised by filtration through the pore, the author points out that were the pores only to communicate from cell to cell, and assuming that Sachs' contention that filtration would readily take place through them is correct, the only effect of such pores would be to equalise the turgidity of the inter-communicating cells, and, therefore, to equalise the growth resulting from that turgidity.

As to the action of such pores if they communicate with the intercellular spaces, or with the exterior, again assuming that free filtration through them is possible, the author answers:—firstly, that such openings would not be expected to communicate commonly with the exterior or with other than neighbouring cells, as where they occur they have probably been in existence from the earliest phases of the cell's life, and the formation of an intercellular space would probably close them, and also that deep pits with closing membranes commonly do not occur in such places. Secondly, bearing in mind the case of the filaments from *Dipsacus sylvestris* to which Fr. Darwin has drawn attention, and the frequency of cilia projected through cell walls in the Thallophyta, the author thinks it by no means proved that such cells cannot become turgescent; and finally asks how the sieve-tubes would withstand the pressures they have to bear if their sieve perforations would destroy turgipotence. He points out that in all these cases the cell sap would still have to pass through protoplasm completely filling the pore; that when the protoplast is in its normal position lining the cell wall, this core of protoplasm filling the pore would offer great resistance to a bodily passage of the cell sap promoted only by the differential pressures of the cells, while molecular passage would take place more easily in other parts of the cell; and, on the other hand, in the plasmolysed cell, filtration through the cell wall would go on too readily to admit of the use of the still 'plugged' pore.

The author then passes on to discuss the possible physiological action of the connecting threads, suggesting that an irritant applied to one cell would cause its protoplast to contract, the threads to be stretched, communicating the stimulus to the surrounding cells, these onwards to the next outer zone, the contraction thus affecting a gradually and rapidly widening area. The whole tissue would then contract by the outward filtration of the cell sap.

He further suggests the possibility that the cells may be made forcibly to contract somewhat through the agency of those threads ('knob-ended') which do not pass through the walls, but retain a hold on the middle lamella at the closing membrane. Knob-ended threads also could transmit impulses.

Finally he brings forward the hypothesis that protoplasm may be endowed with spontaneous expanding powers, similar to its powers of contraction, powers which the known nature of protoplasmic movements renders not unlikely. These expanding powers might be exerted at some one point or in some one direction, and thus define the tendency of the cell to assume a particular form.

The author sums up his conclusions as follows:—

1. That protoplasmic threads connecting neighbouring protoplasts are present in such widely different and diffused structures as sieve-tubes, cortical parenchyma, leaf-pulvinus, pith of resting leaf-bud, and endosperm of seeds.

2. That in the contraction of the protoplast in natural plasmolysis these threads would normally remain unbroken.

3. That they *may* serve to transmit impulses from one cell to another, acting in this way somewhat like a nervous system.

4. That besides the perforating threads, equally widely spread and much more numerous, are threads which attach the protoplast to the cell wall, whether at the base of pits or otherwise; and that these threads are often opposite to each other.

5. That the closing membrane separating two threads often shows differentiation which suggests permeability, if not 'sieve perforation.'

6. That in contraction of the protoplast in natural plasmolysis these threads also would be normally unbroken.

7. That these threads *may* when in extension act upon the cell-wall and put it in a state of slight positive tension.

8. That the presence of minute perforations communicating from cavity to cavity of living cells, *would* not, and if communicating with the intercellular spaces *need* not, be a hindrance to the turgipotence of the cells.

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5. *On some Cell Contents. By* MARSHALL WARD.

The author has for some time past been engaged in researches among the fungi—particularly those which attack living plants, and his attention was necessarily directed to the cell-contents of the host plants: among others, the cells of *Coffea*, *Cinchona*, *Pavetta*, and *Canthium*, and one or two cryptogams have received special attention. The present paper refers particularly to one class of bodies found in the cells of the cultivated species of *Coffea—C. arabica, C. liberica*, &c.

The structure and chemical character of the endosperm have been carefully investigated, and the author gives details of the germination.

Certain fatty bodies, mixed with proteids in the endosperm, are traced into the embryo and seedling, and their reactions and changes are noticed.

In the leaves, cortex, and other soft parts of the mature plant, are found 'fat bodies' under circumstances which compel the author to conclude that they are the results of constructive activity, and not products of destructive metabolism. These 'fat bodies' consist of varying mixtures of fats and other substances—probably in part proteid—and show considerable similarity to the fatty masses in the endosperm.

Details are given of their reactions and changes, and the author believes that they represent temporary stores, to be worked up further in the construction of higher bodies. They may be, in fact, fusions of fatty matters in various stages of transition, carbohydrates, and salts of sulphur, nitrogen, &c., derived from the soil: if so, the author points out that it is not improbable that the earlier constructive acts in the formation of proteids may be taking place here.

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6. *On the Nectar Gland of Reseda.*
By Professor ALEXANDER S. WILSON, *M.A.*, *B.Sc.*

The flowers of this genus, of which the garden mignonette is the best known example, possess in addition to the ordinary floral organs an extra structure named a disk. This disk, which is an expansion of the top of the flower-stalk, is hollow on its upper surface, its shape resembling one-half of a bivalve shell. In this shell-shaped cavity of the disk the honey is secreted, and above it is protected by the three upper petals, the claws of which are flattened and closely overlap, forming a lid which completely closes the nectar-holder. The honey of Reseda is thus contained within a closed box, the lid of which must be prized up before it can be

removed. According to Müller the most frequent visitor to Reseda is the bee Prosopis, which has a flat trowel-shaped proboscis which it uses in plastering its cell.

The nectar gland of Reseda bears such an obvious correlation to this form of proboscis as to favour the conclusion that in Reseda we have a flower specialised for crossfertilisation by short-lipped bees. The slender filiform proboscis of the honey-bee or butterfly is manifestly correlated to deep tubular flowers like Phlox or Honeysuckle, but does not correspond to a nectary like that of Reseda. On the principle that an oyster is more easily opened with a trowel than with a needle, we may regard the box-like nectary of Reseda as corresponding to the short flat proboscis of Prosopis. This points to the probability of Reseda being a very ancient type of flower, since the short-lipped bees belong to an earlier and more generalised type of insect than the specialised honey-gatherers. The condition in the flowers of Reseda is almost the reverse of what we find in the buttercup. In the latter the honey is contained in a little hollow in the petal, and is roofed over by the scale. In Reseda the position of the flower is changed—the scale is hollow and holds the honey, while the petal forms the roof of the nectary.

The scale of Ranunculus and the disk of Reseda are not homologous, and the comparison is only in regard to function. From the examination of the flowers of Reseda from this point of view, we are led to regard them as exhibiting a higher degree of specialisation in relation to insects than has hitherto been suspected. At the same time we see that in them the adaptation is not, as it is in the majority of flowers, most apparent in the calyx, corolla, or stamens, but in the peculiar development of the disk.

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7. *On the Closed Condition of the Seed-vessel in Angiosperms.* *By* Professor ALEXANDER S. WILSON, *M.A.*, *B.Sc.*

Flowering plants may be divided into two classes, according as their seeds are contained within a closed seed-vessel, or are exposed without any such covering. The former, having their seeds included in a pod or pistil, are called Angiosperms or cover-seeded; and the latter, on account of their naked seeds, Gymnosperms. The Angiosperms, which form by far the more important division, embrace most of the common plants which make up the bulk of our flora, and are universally regarded as the more highly organised of the two. Corresponding to the lower degree of organisation, Gymnosperms (yew, cypress, fir, &c.) appear earlier in the geological strata, and are largely represented in a fossil state. The pod of an Angiosperm, such as that of a wall-flower, is composed of metamorphosed leaves termed carpels. In nearly every instance these leaves are so united as to form a completely closed case enveloping the young seeds. At first sight it would seem as if the presence of such a covering were a disadvantage, for before the young seeds or ovules can develop to maturity they require to be fertilised. The process of fertilisation is effected by the agency of pollen-dust which is brought to the flower either by the wind, or by insects visiting the flower in search of honey. Now in the case of Gymnosperms, where the seeds are exposed uncovered, this pollen-dust if blown by the wind simply alights on the surface of the seed and fertilises it directly. In plants with covered seeds, on the other hand, the pollen cannot gain direct access to the ovules, but can only fall on the surface of the envelope formed by the carpellary leaves. This covering has to be penetrated before fertilisation of the seeds can be effected. For this purpose several adaptations of tissues, modifications of structures, and changes in the position of the ovules are rendered necessary, all of which might easily be dispensed with were the seeds exposed as they are in Gymnosperms. It can hardly be supposed that all this specialisation, whereby the process of fertilisation so simply performed in Gymnosperms becomes complicated by being broken up into numerous subsidiary processes, should be called into play unless some very important end were to be attained by the presence of a completely closed pistil. What then is the *rôle* of the pistil? The young seeds are the most vital parts of the vegetable organism. Composed of delicate cells, containing much nitrogen and

phosphorus, they may be said to constitute the chemical and physiological wealth of the plant. On this account they must be carefully guarded from any external influence that would degrade their chemical constitution or lead to a misappropriation of the nutritious matters they contain. Now it is well known that the leaves and stems of nearly all plants are subject to the attacks of parasitic fungi. The spores of these parasites germinate on the leaves of the plant on which they alight, and appropriate its juices to their own use, as, for example, in the case of the fungus which occasions the potato disease. All kinds of moulds, putrefaction, and fermentation are in like manner produced by the development of spores falling from the atmosphere which have found a favourable soil for their growth. Now a more suitable pabulum or nidus for the growth of mould-germs can hardly be imagined than that which would be afforded by the immature ovules, seeing that in them is collected a large amount of easily assimilable matter destined for the nutrition of the embryonic plant. There can be little doubt then that the disadvantages which the pistil brings with it, and the higher organisation thereby entailed, are more than compensated for by the security which it gives against the entrance of fungus spores. The pea pod is in fact the counterpart of the hermetically sealed or stoppered flasks in which Tyndall and Pasteur performed their well-known experiments on the preservation of organic fluids against putrefactive changes. These observers found that it was possible to preserve beef-tea or other organic infusion, for any length of time, provided no air was admitted to the flask, or if care were taken to filter the air from all organic germs, by passing it through cotton wool, &c. before allowing it to have access to the infusion. The pistil of a flower then may be regarded as analogous to the flask in these experiments. The loose cellular substance of the style, and the acid secretion on the stigma, may in like manner serve to filter the air before it reaches the ovules contained within the ovary. At any rate, the air must pass through the substance of the carpels before it can reach the ovules. This view of the function of the carpels is corroborated by the fact observed in the case of Reseda, the carpels of which open soon after fertilisation. After dry weather an accumulation of sand and dust frequently takes place within the ovary of Reseda. When this fact is viewed in connection with the experiments of Van Tieghem, which show how difficult it is to effect the direct fertilisation of ovules with pollen, owing to the constant appearance of microscopic fungi, a new light is thrown on a vast number of vegetable and animal structures. The same principle operates, not only among phanerogams, but even among the cryptogams; nor could a principle of such general application in the vegetable world have failed to play an important part in the animal kingdom. It is remarkable then to find that within the cup of the commonest wild flower we have the results of recent scientific research anticipated, the benefits of the antiseptic system as completely secured as by modern surgery, and a parallel between nature and art which agrees even to the minutest detail.

MONDAY, SEPTEMBER 24.

The following Reports and Papers were read:—

1. *Report on the Record of Zoological Literature.*

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2. *Report of the Committee for aiding in the maintenance of the Scottish Zoological Station.*—See Reports, p. 233.

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3. *Report of the Committee for arranging for the Occupation of a Table at the Zoological Station at Naples.*—See Reports, p. 234.

4. *On two new Dredging Machines.* *By* Professor Milnes Marshall, *M.D.*, *D.Sc.*

The machines in question, named respectively dredging harrow and dredging plough, are examples of apparatus devised for the capture of special organisms and not for general purposes.

The harrow was designed for capturing *Funiculina*, a giant Pennatulid attaining a length of five feet or more. The machine consists of a horizontal bar, four feet long, supported at a height of fifteen inches above the ground by runners; to the bar are attached a number of cords, weighted at their distal ends and bearing a number of triple fish-hooks without barbs. To obviate the danger of the machine falling on the bottom wrong way up, the runners are made in the form of wheels, so that it is immaterial which way up the machine reaches the bottom. The instrument was tried at Oban, and proved very successful.

The plough was intended to dig up *Virgularia*, which owing to its brittleness and length of stalk is usually cut off level with the sea-bottom by the ordinary dredge. It consists of four digging blades attached to a horizontal bar, which, like that of the plough, is furnished with a wheel runner at each end. The machine, like the plough, is made reversible, so that it is immaterial which side reaches the ground first, and special provisions are made to prevent risk of damage from contact with rocks on the sea-bottom.

The plough, which was designed for and used by the Birmingham Natural History Society, worked well, though no opportunity has yet occurred of testing it for the capture of *Virgularia*. It was followed by a large bag to collect the specimens dug up.

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5. *On the Influence of Wave-Currents on the Marine Fauna of shallow seas.* *By* A. R. Hunt, *M.A.*, *F.G.S.*

After showing that the action of alternate wave-currents on the sea-bottom down to a depth of some fifty fathoms could not be safely disregarded by naturalists, owing to the great length of storm-waves, which occasionally attain to and exceed the length of one hundred fathoms (600 feet), the author proceeded to discuss the action of wave-currents on the marine fauna of shallow seas, under the following heads, viz.:—

(1) The influence of wave-currents on animals living on rocks between tide-marks.

(2) The influence of wave-currents on animals living in sand between tide-marks.

(3) The influence of wave-currents on animals living in, or on, sand or mud, below low-water mark.

As a general rule, those animals belonging to the first class referred to above evade the attacks of waves by their powers of adherence to rocks, or by taking refuge in crevices; those of the second class do so by rapidly penetrating the shifting sand in which they live; those of the third class depend for safety on their powers of burrowing and mooring themselves in the sand or mud (being assisted therein by many special adaptations of form and structure), on their powers of attaching themselves to fixed objects, and on their powers of overcoming the wave-currents on the surface of the bottom by virtue of peculiar forms whereby a slighter wave-current suffices to restore them to their normal positions than suffices to overset them.

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6. *On Green Oysters.* *By* Professor E. Ray Lankester, *F.R.S.*

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7. *The Egg-capsules of the Dog-whelk and their contents.* *By* Dr. Carpenter, *C.B.*, *F.R.S.*

8. *New British River-worms.* *By* Professor E. Ray Lankester, *F.R.S.*

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9. *The King Crab and the Scorpion.* *By* Professor E. Ray Lankester, *F.R.S.*

TUESDAY, SEPTEMBER 25.

The following Papers and Report were read:—

1. *An Attempt to Classify Rotifers.* *By* C. T. Hudson.

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2. *The Fauna and Flora of the Ashton-under-Lyne District.* *By* J. R. Byrom.

Immediately after the foundation of the Ashton-under-Lyne Biological Society, in October 1880, the members felt the need of a reliable record of the Fauna and Flora of the neighbourhood. It was therefore resolved that the first and foremost work should be to prepare a list of the Fauna and Flora of the district comprised within a radius of ten miles from the meeting room (Mechanics' Institution), and the following gentlemen have acted as chairmen of the various sections into which the work was divided, viz.:—

FAUNA.	
Mammalia, Aves, Reptilia	Mr. William Beaumont.
Pisces	Mr. William Parkinson.
Protozoa	Mr. Thomas Whitelegge.

FLORA.	
Phanerogams	Mr. John Whitehead.
Cryptogams—	
Filices, Musci, Hepaticæ	" "
Characeæ, Algæ, and Myxomycetes	Mr. Thomas Whitelegge.

These gentlemen have been very kindly assisted by the naturalists of the neighbourhood, and also by other members of the Society, especially our indefatigable secretary, Mr. J. S. Rowse. The result, so far, is the very comprehensive catalogue which I now have the honour to present for your consideration.

The district embraces portions of four counties: Lancashire, Cheshire, Yorkshire, and Derbyshire.

It is traversed by portions of several considerable streams, viz.: the Roch, Irk, Medlock, Irwell, from the Lancashire side; the Tame on the eastern side; the Goyt and Etherow on the south; the last three of which uniting form the Mersey.

The scenery is highly diversified, being generally flat or undulating on the west and south-west, whilst the east and north-east is occupied by the high moorlands of Lancashire, Yorkshire, and Derbyshire; the greatest altitude attained being 1,980 feet, at Kinder Scout in Derbyshire.

The geological structure is also varied, the principal area being covered by various members of the Carboniferous series, including the upper and lower coal measures, which occupy the centre and north-west portion; the Millstone Grits which appear on the east, forming the high lands, whilst the Yoredale shales are found occupying some of the valleys in the same district. Then in the west and south-west we have several strips of Permian rocks, and a large area of New Red Sandstone. There are also immense deposits of drift in various localities, and one or two bog-mosses of considerable extent.

The following is a summary of the Fauna:—

Mammalia	18 species.
Aves	113 „
Reptilia	8 „
Pisces	19 „
Insecta (Moths and Butterflies)	224 „
Protozoa	67 „

The Flora, with some slight exceptions, has been under the care of Mr. John Whitehead, who is well known to scientific botanists as a most assiduous and careful observer, and who has been the means of adding largely to our knowledge of the distribution of plant life in Britain.

Each plant is preceded by a number corresponding with the number of the same species in the 'London Catalogue of British Plants,' 7th ed. The two sets of terms following the common or English name are those used by Mr. H. C. Watson in his 'Cybele Britannica,' the first having reference to the civil claims of the plant, and the second to the usual situation in which the plant may be found with respect to shade or exposure, humidity or dryness, &c. In some instances the first set require qualification, e.g., *Fagus sylvatica*, the Beech, is a native of Britain, but it is not found in our district except where there is every reason to suppose it to have been planted. In all such cases we have retained the proper term as applying to the country, but inserted a qualification along with it—thus:

No. 48, *Nuphar lutea*, Sm. Yellow water lily. Native, lacustral, planted in this district.

About 600 species of Phanerogams have been reported; not many rarities are included, but the following are worthy of remark:—

259. *Hypericum elodes*, Linn.
974. *Scutellaria minor*, Linn.
1288. *Listera cordata*, Brown.
1301. *Malaxis paludosa*, S. W.

are all more or less rare, and are found in Greenfield (Yorkshire), the only locality in this district, and for the latter plant, the only locality in *Yorkshire*; but it is probable they will soon be extinct, as a large waterworks is in course of formation which will probably result in their destruction.

493. *Epilobium obscurum*, Schreb., has been determined lately, and also a very peculiar *Epilobium*, thought by Mr. Charles Bailey to be a hybrid, on account of its abortive seeds, has been found at Marple, growing along with *Epilobium montanum* and *E. hirsutum*. Its characters range with *E. montanum*, and it is of large size.

1213. *Lemna trisulca*, Linn.
1214. *L. minor*, Linn.

have both been found *in flower*. Dr. Boswell remarks in 'English Botany' that he had never seen the flower of the former species.

1310. *Crocus nudiflorus*, Sm., is only marked for eight counties in the 'London Catalogue,' and occurs plentifully in two localities within our district.

590. *Meum athamanticum*, Jacq., also somewhat rare, occurs near Rochdale.

1430. *Carex Boenninghauseniana*, Weihe, a rare carex, is found in Matley Wood, *but only a single hassock.*

The preparation of this catalogue has led to the discovery of many species new to the district, but the most remarkable is a Naias which will probably prove to be *Caulinia Alaganensis*, a species found in Italy and Egypt, and still more recently a Chara has been brought to light which is also new to Britain—most probably *Chara Brawnii*, Gmel.

Musci.

The mosses are arranged according to the 'London Catalogue,' 1880. There are 251 species, which have also been worked out by our Vice-President, Mr. John Whitehead. The district includes some favourable localities, and reaches an altitude of 1,980 feet at Kinder Scout, thus accounting for several alpine and sub-

alpine forms, e.g., *Pogonatum alpinum*, L., *Bryum polymorphum*, *Campylopus atrovirens*, De Not., and *C. paradoxus*, Wils. With respect to the latter species, Dr. Braithwaite, in his new 'Moss Flora,' remarks upon the unusual luxuriance of Mr. Whitehead's specimens.

Buxbaumia aphylla, Hall, is very interesting as occurring at so low an altitude, about 800 feet above sea-level. *Bryum Warneum*, Bland, *B. calophyllum*, R. Br., and *B. turbinatum*, Hedw., occur at gravel-pits near Ashton, only hitherto known near the coast, and in 1865 Professor Schimper made a special journey to see these mosses in so unusual a locality.

Atrichum crispum, James, occurs in abundance at Greenfield and Staley Brushes. When reported from this locality it was only the second station known in Britain; it has, however, since been frequently found, *but only male plants*, the nearest locality known for the female plants being New Jersey, N.A.

Dicranodontium longirostrum, Webb and Mohr., was found here for the first locality in England.

Along with each species we have recorded the time of fruiting.

Hepaticæ.

Of Hepatics 61 species have been determined, and these are also arranged according to the 'London Catalogue,' 1880.

Mr. Holt of Manchester has been responsible for this department, and Mr. W. H. Pearson has kindly verified all the critical species, besides rendering other valuable service.

Amongst the most interesting may be mentioned the following :—

54. *Odontoschisma denudatum*, Nas., rare in this part of the country.

47. *Lepidozia reptans*, L., with an *abundance of fruit*, which is a very rare occurrence.

Lepidozia Pearsoni (Spr.), a species which has been described by Dr. Spruce since the publication of the 'London Catalogue' (see 'Journal of Bot.' 1881, p. 34).

57. *Cephalozia fluitans*, Nes.
88. *Blepharostoma trichophyllum*, L.
105. *Diplophyllum obtusifolium*, Hook.
149. *Jungermannia minuta*, Crantz.

are all recent additions to this district, and somewhat rare in the North of England.

Only three species of *Characeæ* have been recorded, to which the new one must be added, and thirteen species of freshwater Algæ are given.

The Fungi have not yet been attempted, except the Order Myxomycetes, which however is of profound interest to the biologist. These have been carefully investigated by Mr. Thomas Whitelegge, who determined eighteen species, which have been arranged according to 'The Myxomycetes of Great Britain' by M. C. Cooke, 1877.

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3. *On Peripatus.* *By* Adam Sedgwick, *B.A.*

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4. *On Heredity in Cats with an abnormal number of Toes.*[1] *By* E. B. Poulton.

The author gave statistics of the strength of heredity (as shown by the presence and number of abnormal toes) in cats. The peculiarity had been traced for many years through eight generations, and in most cases there was no probability of interbreeding with males of the same stock. In some cases there has been a distinct intensification in the offspring of the character which was only possessed by the mother. Accurate statistics had been obtained from 1879-83.

[1] Published *in extenso* in *Nature* for Nov. 1, 1883.

5. *Report on the Influence of Bodily Exercise on the Elimination of Nitrogen.*—See Reports, p. 242.

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6. *On the Electrical Resistance of the Human Body. By* Dr. W. H. Stone.

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7. *On some Effects of Brain Disturbance on the Handwriting. By* Dr. W. H. Stone.

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8. *On the Muscular Movements that are associated with certain Complex Motions. By* R. J. Anderson, *M.A., M.D.*

When a muscle contracts, one extremity or both extremities may move. When one extremity moves whilst the other is fixed, the fibre may describe a plane surface, as when the moving end lies in a right line or a cone, or as when the moving extremity lies in the circumference of a circle or other plane-curve. If the fibre prove in the plane of the circle, the cone will be reduced to a plane. Where both extremities move the fibre may describe a plane, or a cylinder, or a ruled surface of a high order. It frequently happens that when one extremity of a fibre is fixed, the other extremity moves in a circle, which itself experiences a movement of translation. The moving point then describes a trochoid; examples in pronator teres and pectoralis major. Muscle fibre may describe curves of a complex nature, although the muscles themselves form a simple surface, as in the two muscles already cited.

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9. *On the Annelides of the Southport Sands. By* Dr. Carrington.

These observations were made during a stay of full 18 months at Southport about 20 years since.

The shore at Southport is far from productive. The *littoral zone* extends for nearly a mile to the low-water channel. The surface is composed of a fine granulated sand, intermingled in some spots with mud, and in others forming banks of shell fragments. In no case do we find any fragments of rock or stone large enough for sea-weeds or corallines to cling to, so that practically the *Coralline* and *Laminarian* zones are wanting, or rather the animals and plants characteristic of these zones are for the most part absent. After storms, indeed, the beach is often covered with masses of sea-weed detached from the fishing banks outside, and clinging to these many hydrozoa, sponges, and other marine species may be found.

But these are generally in such a battered and mutilated condition as to be useless for preservation, nor can we justly claim these 'rejectamenta' of the tides as natives of Southport. For example, two species of *Pholas* may occasionally be found (rarely, I believe, *P. candida* has been taken entire), but the nearest known habitat for these species is Hilbro Island, at the mouth of the Dee. As an instance of the selective powers of sea-currents, it may be mentioned that only right-hand valves of *P. candida* are met with at Southport, while at Formby left-hand valves are most numerous.

After the retreat of the tides, the surface is studded with innumerable orifices, some small as the prick of a pin, others as large as the little finger. Leading to these were often stellate serpentine or labyrinthine markings, or evident worm-casts. Near low-water mark on the Birkdale shore, projecting tassels resembling the tag ends of old rope are frequent. These are the terminal tubes of *Terebella,* and the author, on one occasion, by turning over the excavated sand left by a digger for bait, collected about a dozen species of Annelides, some living Heart-Urchins, and a *Sipunculus*. One of these Prof. Macintosh identified with the *Mœa mirabilis,* founded by Dr. Johnson on a solitary fragment dredged on the Scotch coast. This

interesting species, long a puzzle to naturalists, the author afterwards found in some abundance, and was able to study at leisure. It is a slender white worm, having a peculiar cordate leaf-like snout, from the base of which arise two long tentacles studded with rows of conical papillæ. The mobile snout enables it to burrow rapidly through the sand, and when at rest it assumes an erect position below the surface, the long branchiæ waving about in the water. It does not build any tube. Altogether he collected about sixty species during his stay at Southport.

As early as 1745, Bonnet proved that the Naïs and other worms, after division into various parts, after a time regained the power of feeding and reproducing new segments. The slight adhesion between one part and another, and the readiness with which species break up into fragments, is often a source of embarrassment to the collector. Thus, however carefully handled, he was never able to obtain an entire specimen of a very beautiful Polynoe (*P. asterinæ*) which occupied the ambulacral grooves of *Asterinas aurantiaca.*

The species of *Nemertes,* again, without apparent cause, undergo spontaneous sloughing or deliquescence. Many other Annelids, when kept on short commons, undergo a process of budding or fission. This phenomenon can be well studied in *Nais proboscidea,* the new formation taking place in front of the terminal segment. Sometimes as many as four or six individuals are thus interposed between the head and tail of the original worm. In Scyllis and other genera the budding has a sexual import, the detached individuals forming, in fact, locomotive *ovaria.* The production of egg-bearing somites is exhibited on a large scale in such entozoa as the Tape-worms. Dr. Williams, in his *Report on Annelids* (British Association, 1851), denies the whole of what Bonnet and others have recorded respecting the reproduction of lost parts in *Annelids,* although he admits a process of gradual sloughing from injury or starvation; but the phenomena have been noted too frequently by independent students to leave any doubt respecting them. It would be out of place to enter into any structural details. In all Annelides the division into segments (of which the common worm is a typical example) prevails—only, instead of the simple bead-like structure, new organs are superadded, so as to fit the species for progression in the pursuit of prey (Errantia), or for swimming (Phyllodoce), or burrowing in the sand.

In the sedentary species the anterior portion is still further modified by the addition of tentaculæ, so as to enable the individual to search for food or materials for constructing its tube: or designed for the protection of delicate parts (such as the branchiæ) from the encroachments of enemies. Examples of this kind may be found in the cork-like stopper of *Serpula,* which effectually closes the mouth of the tube. A similar protection from enemies is seen in the crescentic coronal of *Hermella,* and the golden combs of *Pectinaria.* Lastly, the contrivances for the *aëration* of the red fluid we may call the blood, are remarkably varied and beautiful. They advance from a simple ciliated process given off from each segment, through every grade of complexity, to the shrub-like ramifications of *Arenicola.* The colouring of the species is equally variable: white, flesh-tinted, ruby-red, sea-green, violet: the surface often glowing with pearly or metallic iridescence. When we remember that the Annelides, constituting the chief food of many fish, birds, and crustacea, are subject to the attacks of various enemies, and that their delicate bodies are liable to constant mutilation from the drifting of the sands and the action of the waves, we see the reason for the recuperative power they possess. The author mentioned a remarkable instance of survival under difficulties exhibited by a *Terebella* which was packed away among his books when he left Southport. The specimen was a mature worm with a portion of the tube, left in the bottle just as he collected it, with a little sea-water and sand. On opening the box four months afterwards, the creature was still living, although reduced to a mere stump. During the interval it had actually carried the tube, growing thinner and more transparent from lack of material, three times round the bottle.

The higher order of Annelids, the *Errantia,* are represented only by those species which can bury themselves in the sand. In the absence of the shelter afforded by vegetation, by boulders or the holes and crevices on rocky shores, where

these shy creatures love to hide themselves, every old shell should be examined. He had found the empty shells of the Whelk most productive. One specimen which a Hermit-crab had appropriated proved a veritable Noah's Ark. On the outside it was encrusted with colonies of Hydrozoa, within the mouth he found a patch of *Hermella*; and associated with this species, a minute *Sipunculus* and a delicate worm often found in the substance of old shells (*Leucodore*). Even then the list was incomplete; on breaking open the shell he exposed lurking within the terminal spiral, one of the finest species of Nereis (*N. bilineata*), and lastly, two or three youthful *serpulæ*.

The following list is far from exhaustive, the object having been to indicate the characteristic sand-worms.

Critical species have been identified by Prof. Macintosh. *Nematoid worms*, many of which are found near low-water mark, have been omitted.

1. Errantes.

Amphinomadæ.

Aphrodite aculeata, L.—Found sparingly in wet hollows after high tides.

Pholoë Baltica (?).—Only one specimen.

Polynoa squamata, Sav.—Rare, within old shells, frequently among the refuse from fishing boats.

Polynoa asterinæ.—Occupying the groove between the suckers of *Asterias aurantiaca.* My attention was first directed to this species by observing a blue phosphorescence given off from one or more rays when the Star-fish was plunged into fresh water. The worm is long and flesh-coloured, the scales entire, with a black border.

Sigalion Mathildæ.—A beautiful species with fringed pearly scales, not uncommon, coiling round the tubes of *Terebella.*

2. Nereida.

Nereis pelagica, L.—Among the refuse of oyster beds we find the ordinary pinkish forms. But occupying burrows in damp places another variety is frequent, of a deep velvety green or orange colour, which may be the *N. viridis*, L.

Another form abounds near high-water mark, from which the tide is absent for months together. The feet are longer, and the colour orange shaded with olive.

N. bilineata, Johns.—Occupying the terminal whorl of old whelks, generally associated with *Pagurus Barnhardus.*

Nepthys margaritacea, Sars.

N. Hombergii, Sars.—Several species of *Nepthys* are common in the sand. Some specimens were from six to eight inches long, and as thick as the little finger. From the habit of suddenly everting the formidable proboscis, they look very threatening.

Phyllodore lamelligeus, Johns.—Not unfrequent.

Scyllis prolifera, Matt.—Frequent in muddy hollows.

Pollicita peripatus, Johns.—Very rare.

Goniada maculata, Johns.—Only one specimen.

Glycera alba.—Very rare.

Ariciæ.—Occupying burrows in the sand.

Nerine vulgaris, Johns.—Very rare.

N. coniocephala, Johns.—Not uncommon in muddy hollows about mid-tide. This lovely species occupies a friable tube, descending a foot or more. The body is pellucid green, crossed by carmine bands (the branchial processes).

Leucodore ciliatus, Johns.—Common in old shells.

Mœa mirabilis, Johns.—Found in some abundance near low water in a muddy spot opposite Broad Slalk, Birkdale.

Arenicola piscatorum, L.—Common.

3. Tubicoles, Cuv.

(*a*) Tubes arenaceous.

Pectinaria Belgica, L.—Common near deep water.

Sabellaria alveolata, Lam. (*Hermella,* Quart.) Frequent within the mouth of old shells.

S. crassissima, Lam.—Occasional.

Owenia filiformis, Della Chijsa (*Ammochares Ottonis,* Grub.). Sparsely distributed. Tube about the thickness of a crow-quill, covered with short angular shell fragments, closely imbricating each other. Allied to *Clymene.*

Terebella arenaria, L.—Abundant on the Birkdale shore near low water.

T. conchilega, Poll.

T. nebulosa, Mont.—Attached to shells and roots of ferns cast up after storms.

Serpula contortuplicata, S. triquetra, and several varieties of *Spirorbis* and *Sabella,* are also found among the roots of Laminaria, &c., drifted from without.

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10. *On Protoplasmic Continuity in the Florideæ.* *By* THOMAS HICK, *B.A., B.Sc.*

In the hope of throwing some light upon the interesting and important question of protoplasmic continuity in vegetable tissues, the author has made an extensive series of observations on a large number of species, belonging to several genera of Florideæ, with special reference to this question. He finds that in every species hitherto examined, the histological structure is such that, except where accidentally interrupted, there is an unbroken continuity of the protoplasmic substances of the plant from the base of the frond to the tips of the ultimate branchlets. In the normal condition the protoplasmic body of every cell is connected, by means of one or more protoplasmic threads, with the protoplasmic bodies of contiguous cells, however numerous these may be. These threads pass through apertures in the cell walls, by which the contents of the respective cells are separated.

In the simpler filamentous forms, such as *Petrocelis cruenta, Griffithsia setacea, Callithamnion Rothii,* and the like, the mode in which continuity is effected is comparatively simple. In these cases the contents of each cell are connected longitudinally with the contents of the next higher or lower cell by a single, fine, protoplasmic thread, lateral connections only appearing where the basal cell of a branch is connected with a cell of the main axis.

The stouter forms of *Callithamnion,* e.g. *C. tetragonum* and *C. arbuscula,* are provided with a cortex composed of filaments which arise from the bases of the lateral branches, and, growing downwards, become adherent to the axial cells. In this cortex, as well as in the axis itself, protoplasmic continuity is a marked feature, an important point being that in the larger and older cells the protoplasmic connections are no longer fine threads, but comparatively stout cords.

In genera where the thallus obtains a higher degree of complexity, the arrangements for the maintenance of continuity are more elaborate. Professor E. P. Wright has shown that in *Polysiphonia urceolata, P. fibrata,* and *P. atrorubescens,* the protoplasmic bodies of the central siphon are longitudinally connected, as are also those of the cortical siphons; while the contents of each central cell are similarly connected by transverse radial threads with those of the surrounding cortical cells. The author's observations go to prove that substantially the same phenomena are met with through the whole genus, and are especially striking and easy to make out in *P. fastigiata.*

The genus *Ceramium* has a structure differing from that of *Polysiphonia* in many respects, but agreeing with it in presenting a thallus consisting of a central axial row of cells, usually clothed to a greater or less extent by a cortex. By careful manipulation and the aid of sections, it is not difficult to demonstrate protoplasmic connections between the cells, similar to those already mentioned. Such connections render the protoplasm of the axial cells continuous from one end to the other, and bring these cells into direct communication with the cells of the cortex. In this genus, however, the connection between contiguous cells is made by two or more threads, and not by a single one, as in *Polysiphonia, Callithamnion,* &c. In *Ceramium rubrum,* for instance, the cortical cells are often connected by four or

five protoplasmic threads, a feature which gives sections of this plant a most characteristic appearance.

The genus *Ptilota*, so much admired for the beauty of its forms, is no less remarkable for the striking examples it offers of protoplasmic continuity. This is especially true of *P. elegans*. Fundamentally monosiphonous, so to speak, the older parts of this species become densely corticated, though the ultimate divisions of the frond are simple filaments composed of oblong or quadrate cells. The protoplasmic bodies of these cells are in uninterrupted continuity, and the basal cell of each branchlet is connected with a cell of the branch from which it springs. From these ultimate branchlets the continuity may be traced backwards without a break to the main axis of the frond, along which it may be followed by the help of sections. The cells of the cortex are likewise connected *inter se*, and with those of the axis they enclose, so that here, too, the contents of the different cells are in direct communication throughout the whole plant.

Other genera, in which corresponding appearances are presented, are *Wormskioldia*, *Delesseria*, *Plocamium*, *Cystoclonium* (*Hypnea*), *Gigartina*, and *Chondrus*. Of these the author has examined numerous species, with the result that in no single instance are the connecting threads of protoplasm running from cell to cell absent. To describe the phenomena in detail would be to repeat what has already been said. *Chondrus* and *Gigartina* may be referred to as differing histologically from the other genera, and, indeed, from one another; but they are at one with them in the matter of protoplasmic continuity.

Of all the genera examined one of the most interesting, from the point of view of this paper is *Laurencia*. In *L. pinnatifida* the size, shape, and arrangement of the cells vary much in different parts of the thallus, but in every part the protoplasmic bodies present a most remarkable appearance. From the surface of each, at various points, are given off radiating processes, which run along channels or pits in the thickened wall, and finally meet and blend with similar processes from the adjoining cells. These processes are invariably so stout and distinct as to give to the cell-contents the appearance of a Rhizopod with short thick pseudopodia.

Of fresh-water Florideæ, the author has examined *Batrachospermum* and *Chantransia*, both of which exhibit evidences of continuity.

Coming to the question of origin the author is of opinion that the connecting protoplasmic threads under consideration, originate, as a rule, in the manner described by Professor E. P. Wright for *Polysiphonia urceolata*. As a matter of fact, the process of cell-division in the Florideæ here dealt with, and probably in all, never becomes completed, so that the parts of a divided cell remain connected together by one or more threads of protoplasmic material. Nor are these threads merely temporary structures. On the contrary, save where accidentally broken, they are permanent, being met with in the older parts of the plant as constantly as in the younger. Again, these threads are not dead, but possess the vitality and power of growth of ordinary protoplasm. This is proved by the facts that, as a rule, they become stouter with age, and give rise to differentiated structures. For, simultaneously with the thickening of the threads, a peculiar structure is developed by each at about its middle point. This usually presents itself in the shape of a ring or collar, as may be readily seen in *Callithamnion*, *Polysiphonia*, *Laurencia*, and other genera. In some cases an extremely thin diaphragm is developed within this collar. The nature of this it is difficult to determine, but that it is not a cellulose partition seems to be indicated in many ways. For instance, it colours with iodine and aniline dyes in the same way as the protoplasm, while the cellulose walls are altogether unaffected. Moreover, when by desiccation of the specimen the protoplasm shrinks from the cell wall, it does not shrink from the ring and diaphragm, continuity being as perfect in dried material as in fresh. Lastly, when the continuity is broken mechanically, the fracture may occur at any point of the thread, and not necessarily at the collar.

11. *On some newly-discovered localities of the rare Slug, Testacella Haliotidea. By* E. J. Lowe, *F.R.S.*

This rare and hitherto extremely local meat-eating slug has recently been found in various places in Monmouthshire and South Wales. Having found a few examples in my kitchen gardens at Shirenewton Hall, I made an extended search with the following result:—

Shirenewton Hall Kitchen Gardens (four and a half miles from Chepstow).—120 examples were collected in less than an hour; six of these were eating worms and one was devouring an *Arion hortensis.* In the gardens and fernery, nearly half a mile from the kitchen gardens, six more specimens were obtained.

Shirenewton Village.—Cottage gardens and a field added a few more examples.

Itton Court (three miles from Chepstow).—Several specimens.

Between Chepstow and Shirenewton, in a lane (about half-way).—A single specimen.

Hardwick (half a mile from Chepstow).—Abundant.

Chepstow (in several gardens and on the road to Portskewett).—Plentiful.

Cardiff (in Dr. Vachell's garden).—Common.

Further search will no doubt add considerably to the localities of this interesting but little known species.

As an instance of their destruction to worms and other slugs, it may be stated that twenty-five fully-grown specimens were put in a slug cage with twenty-five worms and the same number of *Limax agrestis* and *Arion hortensis*, and in twenty-four hours they had eaten the whole of them.

DEPARTMENT OF ANTHROPOLOGY.

Chairman of the Department—W. Pengelly, F.R.S., F.G.S.
(Vice-President of the Section.)

THURSDAY, SEPTEMBER 20.

The Chairman delivered the following Address:—

Anthropology, on one of its numerous sides, marches with Geology; and hence it is, no doubt, that I, for many years a labourer very near this somewhat ill-defined border, have been invited to assist my friends and neighbours in the work which lies before them during the Association week. I have the more cheerfully accepted the invitation from a vivid recollection that when on a few occasions I have come uninvited into this Department, my reception has been so very cordial as to lead me to ask myself whether the Reports which for many years (1864 to 1880) I laid annually before my geological brethren did not derive their chief interest from their anthropological bearings and teachings.

In 1858—a quarter of a century ago—I had the pleasure of reading to the Geological Section of the Association the first public communication on the exploration, then in progress, of Brixham Cavern (more correctly, Brixham Windmill-Hill Cavern); and as any interest connected with that paper lay entirely in the evidence it contained of the inosculation and contemporaneity of Human Industrial Relics, of a rude character, with remains of certain extinct mammals, I purpose on this occasion to lay before the Department a few thoughts, retrospective and

prospective, which may be said to radiate from that exploration; confining myself mainly to South Devon.

Probably nothing will better show the apparent apathy and scepticism with which, up to 1858, all geological evidence of the Antiquity of Man was received by British geologists generally, than the following statement of facts:—

About the beginning of the second quarter of the present century the late Rev. J. MacEnery made Kent's Cavern, or Kent's Hole, near Torquay, famous by his researches and discoveries there. He not only found flint implements beneath a thick continuous sheet of stalagmite, but, after a most careful painstaking investigation in the presence of witnesses, arrived at the conclusion that the flints 'were deposited in their deep position before the creation of the stalagmite' (*Trans. Devon. Assoc.* iii. 330); and when it was suggested by the Rev. Dr. Buckland, to whom he at once and without reservation communicated all his discoveries, that 'the ancient Britons had scooped out ovens in the stalagmite, and that through them the knives got admission to the "diluvium,"' he replied, 'I am bold to say that in no instance have I discovered evidence of breaches or ovens in the floor, but one continuous plate of stalagmite diffused uniformly over the loam' (*Ibid.* p. 334). He added, 'It is painful to dissent from so high an authority, and more particularly so from my concurrence generally in his views of the phenomena of these caves, which three years' personal observation has in most every instance enabled me to verify' (*Ibid.* p. 338).

It is, perhaps, not surprising that Dr. Buckland, one of the leading geologists of his day, should be too tenacious of his opinion, and feel too secure in his position to yield to the statements and arguments of his comparatively young friend MacEnery, then scarcely known to the scientific world.

That the position taken by Buckland retarded the progress of truth, and was calculated to check the ardour of research, is apparently certain, and much to be regretted; but it should be remembered that, at least, as early as 1819 he taught that 'the two great points . . . of the low antiquity of the human race, and the universality of a recent deluge, are most satisfactorily confirmed by everything that has yet been brought to light by Geological investigations' (*Vindiciæ Geologicæ*, p. 24); that early in 1822 he reiterated and emphasized these opinions in his famous *Kirkdale* paper (*Phil. Trans.* for 1822, pp. 171–236), which the Royal Society "crowned with the Copley medal" (*Quart. Journ. Geol. Soc.* vol. xiii. p. xxxiii); that in 1823, having amplified and revised this paper, he published it as an independent quarto volume under the attractive title of *Reliquiæ Diluvianæ*, of which he issued a second edition in 1824; and that though his acquaintance with Kent's Cavern was much less intimate than that of MacEnery, he, nevertheless, was, of the two, the earlier worker there, and in fact had discovered a flint implement in it before MacEnery had ever seen that or any other cavern—the first tool of the kind found in any cavern, it is believed, which in all probability was met with under circumstances not in conflict with his published opinion on the low antiquity of man. I confess that under such circumstances, human nature being what it is, the line followed by Dr. Buckland seems to me to have been that which most men would have pursued.

It was, at any rate, the line to which he adhered as late, at least, as 1837; for in his well-known *Bridgewater Treatise*, published that year, after describing his visit to the caverns near Liège, famous through the discoveries of Dr. Schmerling, he said: 'The human bones found in these caverns are in a state of less decay than those of the extinct species of beasts; they are accompanied by rude flint knives and other instruments of flint and bone, and are probably derived from uncivilised tribes that inhabited the caves. Some of the human bones may also be the remains of individuals who, in more recent times, have been buried in such convenient repositories. M. Schmerling . . . expresses his opinion that these human bones are coeval with those of the quadrupeds, of extinct species, found with them; an opinion from which the Author, after a careful examination of M. Schmerling's collection, entirely dissents' (*op. cit.* i. 602).

It may be doubted, however, whether his faith in these, his early, convictions

remained unshaken to the end. I have frequently been told by one of his contemporary professors at Oxford, who knew him intimately, that Buckland shrank from the task of preparing for the press new editions of his *Reliquiæ Diluvianæ* and his *Bridgewater Treatise.* 'The work,' he said, 'would be not editing, but re-writing.'

Mr. MacEnery intended to publish his 'Cavern Researches,' in one volume quarto, illustrated with thirty Plates. In what appears to have been his second prospectus, unfortunately not dated, he said 'The limited circulation of works of this nature, being by no means equal to the expenses attendant on the execution of so large a series' [of Plates], 'the author is obliged to depart from his original plan, and to solicit the support of those who may feel an interest in the result of his researches.'

There is reason to believe that at least twenty-one of the Plates were ready, and that the rough copy of much of his manuscript was written; but that, the support he solicited not being forthcoming, the idea of publishing had to be abandoned. (See *Trans. Devon. Assoc.* iii. 198–201.)

In 1840, Mr. R. A. C. Austen (now Godwin-Austen), F.G.S., read to the Geological Society of London a paper on *The Bone Caves of Devonshire,* which with some amplifications was incorporated in his Memoir *On the Geology of the South-East of Devonshire,* printed in the *Transactions* of the Society in 1842 (2nd Ser., vi. 433–489). Speaking of his own researches in Kent's Cavern, he said: Human remains and works of art, such as arrow-heads and knives of flint, occur in all parts of the cave and throughout the entire thickness of the clay: and no distinction founded on condition, distribution, or relative position, can be observed, whereby the human can be separated from the other reliquiæ' (*Ibid.* p. 444).

He added: 'My own researches were constantly conducted in parts of the cave which had never been disturbed, and in every instance the bones were procured from beneath a thick covering of stalagmite; so far then, the bones and works of man must have been introduced into the cave before the flooring of stalagmite had been formed' (*Ibid.* p. 446).

Though these important and emphatic statements were so fortunate as to be committed to the safe keeping of print with but little delay, and under the most favourable circumstances, they appear neither to have excited any interest, nor indeed to have received much, if any, attention.

In 1846, the Torquay Natural History Society appointed a Committee, consisting of Dr. Battersby, Mr. Vivian, and myself—all tolerably familiar with the statements of Mr. MacEnery and Mr. Austen—to make a few diggings in Kent's Cavern for the purpose of obtaining specimens for their Museum. The work, though more or less desultory and unsystematic, was by no means carelessly done, and the Committee were unanimously and perfectly satisfied that the objects they met with had been deposited at the same time as the matrix in which they were inhumed. At the close of their investigation they drew up a Report, which was printed in the *Torquay Directory* for November 6, 1846. (See *Trans. Devon. Assoc.* x. 162.) Its substance, embodied in a paper by Mr. Vivian, was read to the Geological Society of London, on May 12, 1847, as well as to the British Association in the succeeding June; and the following Abstract was printed in the *Report* of the Association for that year (p. 73):—

'The important point that we have established is, that relics of human art are found *beneath* the unbroken floor of stalagmite. After taking every precaution, by sweeping the surface, and examining most minutely whether there were any traces of the floor having been previously disturbed, we broke through the solid stalagmite in three different parts of the cavern, and in each instance found flint knives. . . . In the spot where the most highly finished specimen was found, the passage was so low that it was extremely difficult, with quarrymen's tools and good workmen, to break through the crust; and the supposition that it had been previously disturbed is impossible.'

It will be borne in mind that the same paper was read the month before to the Geological Society. The Council of that body, being apparently unprepared to print in their *Quarterly Journal* the statements it contained, contented themselves with the following notice, given here in its entirety (*op. cit.* iii. 353):—

"*On* KENT'S CAVERN *near* TORQUAY, by EDWARD VIVIAN, Esq.—In this paper an account was given of some recent researches in that cavern by a committee of the Torquay Natural History Society, during which the bones of various extinct species of animals were found in several situations."

It will be observed that the 'flint knives' were utterly ignored; a fact rendered the more significant by the following announcement on the wrapper of the Journal: 'The Editor of the *Quarterly Journal* is directed to make it known to the public that the authors alone are responsible for the facts and opinions contained in their respective papers.'

Such, briefly, were the principal researches in Kent's Cavern, at intervals from 1825 to 1847. Their reception was by no means encouraging: Mr. MacEnery, after incurring very considerable expense, was under the necessity of abandoning the intention of publishing his *Cavern Researches*; Mr. Austen's paper, though printed unabridged, was given to an apathetic unbelieving world, and was apparently without effect; and Mr. Vivian's paper, virtually the Report by a Committee of which he was a member, was cut down to four lines of a harmless unexciting character.

For some years nothing occurred to break the quietude, which but for an unexpected discovery on the southern shore of Torbay would probably have remained to this day.

Early in 1858, the workmen engaged in a limestone quarry on Windmill Hill, overhanging the fishing town of Brixham in South Devon, broke unexpectedly a hole through what proved to be the roof of an unknown and unsuspected cavern. I visited it very soon after the discovery, and secured to myself the refusal of a lease to include the right of exploration. As the story of this Cavern has been told at some length elsewhere (see *Phil. Trans.* clxiii. 471–572; or *Trans. Devon. Assoc.* vi. 775–856), it will here suffice to say that at the instance of the late Dr. H. Falconer, the eminent palæontologist, the subject was taken up very cordially by the Royal and Geological Societies of London, a Committee was appointed by the latter body, the exploration was placed under the superintendence of Mr. (now Professor) Prestwich and myself, and, being the only resident member of the Committee, the actual superintendence fell of necessity to me.

The following facts connected with this Cavern were no doubt influential in leading to the decision to have it explored:—

1st. It was a virgin cave which had been hermetically sealed during an incalculably long period, the last previous event in its history being the introduction of a Reindeer antler, found attached to the upper surface of the stalagmitic floor. It was therefore free from the objection urged sometimes against Kent's Cavern, that, having been known from time immemorial, and, up to 1825, always open to all comers, it had, perhaps, been ransacked again and again.

2nd. It was believed, and it proved, to be a comparatively very small cavern, so that its complete exploration was not likely to require a large expenditure of time or of money.

It will be seen that the exploration was placed under circumstances much more likely to command attention than any of those which had preceded it. It was to be carried on under the auspices of the Royal and Geological Societies, by a Committee consisting of Mr. S. H. Beckles, Mr. G. Busk, Rev. R. Everest, Dr. H. Falconer, Mr. Godwin-Austen, Sir C. Lyell, Professor Owen, Dr. J. Percy, Mr. J. Prestwich, Professor (now Sir A. C.) Ramsay, and myself—all Fellows of the Geological Society, and almost all of them of the Royal Society also.

It was impossible not to feel, however, that the mode of exploration must be such as would not merely satisfy those actually engaged in the work, but such as would command for the results which might be obtained the acceptance of the scientific world generally. Hence I resolved to have nothing whatever to do with

'trial pits' here and there, or with shafts to be sunk in selected places; but, first, to examine and remove the stalagmitic floor; then, the entire bed immediately below (if not of inconvenient depth) horizontally throughout the entire length of the cavern, or so far as practicable; this accomplished, to proceed in like manner with the next lower bed; and so on until all the deposits had been removed.

This method, uniformly followed, was preferable to any other, because it would reveal the general stratigraphical order of the deposits, with the amount and direction of such 'dip' as they might have, as well as any variations in the thickness of the beds; it would afford the only chance of securing all the fossils, and of thus ascertaining, not only the different kinds of animals represented in the Cave, but also the ratios which the numbers of individuals of the various species bore to one another, as well as all peculiar or noteworthy collocations; it would disclose the extent, character, and general features of the Cavern itself; it was undoubtedly the least expensive mode of exploration; and it would render it almost impossible to refer bones or indications of human existence to wrong beds, depths, or associations.

The work was begun in July 1858, and closed at the end of twelve months, when the Cavern had practically been completely emptied; an official Report was printed in the *Philosophical Transactions* for 1873, and all the specimens have been handed over to the British Museum.

The paper on the subject mentioned at the beginning of this Address was read in September 1858, during the Meeting of the Association at Leeds, when I had the pleasure of stating that eight flint tools had already been found in various parts of the Cavern, all of them inosculating with bones of mammalia, at depths varying from 9 to 42 inches in the Cave-earth, on which lay a sheet of Stalagmite from 3 to 8 inches thick; and having *within* it and *on* it relics of Lion, Hyæna, Bear, Mammoth, Rhinoceros, and Reindeer.

It soon became obvious that the geological apathy previously spoken of had been rather apparent than real. In fact, geologists were found to have been not so much disinclined to entertain the question of Human Antiquity, as to doubt the trustworthiness of the evidence which had previously been offered to them on the subject. It was felt, moreover, that the Brixham evidence made it worth while, and indeed a duty, to re-examine that from Kent's Cavern, as well as that said to have been met with in river deposits in the valley of the Somme and elsewhere.

The first-fruits, I believe, of this awakening was a paper, by Mr. Prestwich, read to the Royal Society, May 26, 1859, *On the Occurrence of Flint Implements, associated with the Remains of Animals of Extinct Species in Beds of a late Geological Period, in France at Amiens and Abbeville, and in England at Hoxne.* (*Phil. Trans.* for 1860, pp. 277–317.) This paper contains explicit evidence that Brixham Cavern had had no small share in disposing its author to undertake the investigation, which added to his own great reputation, and rescued M. Boucher de Perthes from undeserved neglect. 'It was not,' says Mr. Prestwich, 'until I had myself witnessed the conditions under which these flint-implements had been found at Brixham, that I became fully impressed with the validity of the doubts thrown upon the previously prevailing opinions with respect to such remains in caves' (*op. cit.* p. 280).

Sir C. Lyell, too, in his Address to the Geological Section of the British Association, at Aberdeen, in September 1859, said, 'The facts recently brought to light during the systematic investigation, as reported on by Dr. Falconer, of the Brixham Cave, must, I think, have prepared you to admit that scepticism in regard to the cave-evidence in favour of the antiquity of man had previously been pushed to an extreme' (*Report Brit. Assoc.* 1859, *Trans. Sects.* p. 93).

It is probably unnecessary to quote further to show how very large a share the Exploration at Brixham had in impressing the scientific world generally with the value and importance of the geological evidence of Man's Antiquity. That impression, begun as we have seen in 1858, has not only lasted to the present day, but has probably not yet culminated. It has produced numerous volumes, crowds of papers, countless articles in Reviews and Magazines, in various countries; and,

perhaps, in order to show how very popular the subject became almost immediately, it is only necessary to state that Sir C. Lyell's great work on the *Antiquity of Man* was published in February 1863, the second edition appeared in the following April, and the third followed in the succeeding November—three editions of a bulky scientific work in less than ten months! A fourth edition was published in May 1873.

Few, it may be presumed, can now doubt that those who before 1858 believed that our fathers had under-estimated Human Antiquity, and fought for their belief, have at length obtained a victory. Nevertheless, every Anthropologist has doubtless, from time to time,

'Heard the distant and random gun
That the foe was sullenly firing.'

The 'foe,' to speak metaphorically, seems to consist of very irregular forces, occasionally unfair but never dangerous, sometimes very amusing, and frequently but badly armed or without *any* real armour. The Spartan law which fined a citizen heavily for going into battle unarmed was probably a very wise one.

For example, and dropping metaphor, a pamphlet published in 1877 contains the following passage: 'With regard to all these supposed flint implements, and spear and arrow heads, found in various places, it may be well to mention here the frank confession of Dr. Carpenter. He has told us, from the Presidential Chair of the Royal Academy, that "No logical proof can be adduced that the peculiar shapes of these flints were given them by human hands."' (See *Is the Book Wrong? A Question for Sceptics*, by Hely H. A. Smith, p. 26.) The words ascribed to Dr. Carpenter are put within inverted commas and are the whole of the quotation from him. I was a good deal mystified on first reading them, for while it seemed likely that the President spoken of was the well-known member of this Association—Dr. W. B. Carpenter—it was difficult to account for his being in the Presidential Chair of the Royal Academy, and not easy to understand what the Royal Academy had to do with flint implements. A little search, however, showed that the Address which Dr. W. B. Carpenter delivered in 1872 from the Presidential Chair of, not the Royal Academy, but the British Association, contained the actual words quoted, followed immediately by others which the author of the pamphlet fonnd it inconvenient to include in his quotation. Dr. Carpenter, speaking of 'Common Sense,' referred, by way of illustration, to the 'flint implements' of the Abbeville and Amiens gravel-beds, and remarked: 'No logical proof can be adduced that the peculiar shapes of these flints were given to them by Human hands; but does any unprejudiced person now doubt it?' (*Report Brit. Assoc.* 1872, p. lxxv). Dr. Carpenter, after some further remarks on the 'flint implements,' concluded his paragraph respecting them with the following words: 'Thus what was in the first instance a matter of discussion, has now become one of those "self-evident" propositions which claim the unhesitating assent of all whose opinion on the subject is entitled to the least weight.'

It cannot be doubted that, taken in its entirety—that is to say, taken as every lover of truth and fairness should and would take it—Dr. Carpenter's paragraph would produce on the mind of the reader a very different effect to that likely, and no doubt intended, to be produced by the mutilated version of it given in the pamphlet.

A second edition of the pamphlet has been given to the world. Dr. Carpenter is still in the Presidential Chair of the Royal Academy, and the quotation from his Address is as conveniently short as before.

It would be easy to bring together a large number of similar modes of 'defending the cause of truth'—to use the words of the pamphlet just noticed—but space and time forbid.

I cannot, however, forego the pleasure of introducing the following recent and probably novel explanation of cavern phenomena. In 1882 my attention was directed to two articles, by one and the same writer, on *Bone-Cave Phenomena*. The writer's theme was professedly the Victoria Cave, near Settle, Yorkshire,

which he says was an old Roman lead mine, but his remarks are intended to apply to Bone-Caves in general. He takes a very early opportunity in the second article of stating that 'We shall have to take care to distinguish between what is truly indicated in the "Science" view, from what are purely imaginary exaggerations of its natural and historical phenomena'; and he no doubt believes that he has taken this care.

'We have now,' he says, 'to present our own view of the Victoria Cave and the phenomena connected with it, premising that a great many of the old mines in Europe were opened by Phœnician colonists and metal-workers, a thousand years before the Romans had set foot in Britain, which accounts for the various floors of stalagmite found in most caves, and also for the variety of groups of bones embedded in them. The animals represented by them when living were not running wild about the hills devouring each other, as science-men suppose, but the useful auxiliaries and trained drudges of the miners in their work. Some of them, as the bear, had simply been hunted and used for food, and others of a fierce character, as the hyæna, to frighten and to keep in awe the native Britons. The larger species of mammalia, as the elephant, the rhinoceros and hippopotamus, and beasts foreign to the country, the Romans no less than the Phœnicians, had every facility in bringing with them in their ships of commerce from Carthage, or other of the African ports. These, with the native horse, ox, and stag, which are always found in larger numbers in the caves than the remains of foreign animals, all worked peacefully together in the various operations of the mines. . . . The hippopotamus, although amphibious, is a grand beast for heavy work, such as mining, quarrying, or road-making, and his keeper would take care that he was comfortably lodged in a tank of water during the night. . . . The phenomena of the Victoria Cave Lead Mine differs in no material respect from that of hundreds of others, whether of lead, copper, silver, or iron, worked in Roman and pre-Roman times in all parts of Europe. Its tunnels have all been regularly quarried and mined, *not by ancient seas*, but by the hands of historic man. Double openings have been made in every case for convenient ingress and egress, during the process of excavation. Its roadways had been levelled, and holes made up with breccia, gravel, sand, and bones of beasts that had succumbed to toil, on which sledges, trolleys, and waggons could glide or run. . . . Near the entrance inside Victoria Cave were found the usual beds of charcoal and the hearths for refining the metal, while close by on the hill-side may still be seen the old kilns in which the men "roasted" the metallic ores and burned lime.'

Should anyone be disposed to ascribe these articles to some master of the art of joking, it need only be replied that they appeared in a religious journal (*The Champion of the Faith against Current Infidelity*, for April 20, and May 11, 1882, vol. i. pp. 5 and 26), with the writer's name appended; and that I have reason to believe they were written seriously and in earnest.

It has been already intimated that Brixham Cavern has secured a somewhat prominent place in literature; and it can scarcely be needful to add that some of the printed statements respecting it are not quite correct. The following instances of inaccuracy may be taken as samples.

The late Professor Ansted, describing Brixham Cavern, in 1861, said: "In the middle of the cavern, under stalagmite itself, and actually entangled with an antler of a reindeer and the bones of the great cavern bear, were found rude sculptured flints, such as are known to have been used by savages in most parts of the world.' (*Geological Gossip*, p. 209.)

To be 'entangled' with one another, the antler, the bones of the Cave-bear, and the flints must have been all lying together. As a matter of fact, however, the antler was *on* the upper surface of the sheet of stalagmite, while all the relics of the Cave-bear, and all the flints were in detrital beds below that sheet. Again, the flints nearest the bear's bones in question were two in number; they were twelve feet south of the bones, and fifteen inches less deep in the bed. There was no approach to entanglement.

Should it be suggested that it is scarcely necessary to correct errors on

scientific questions in works, like *Geological Gossip*, professedly popular and intended for the million, I should venture to express the opinion that the strictest accuracy is specially required in such books, as the great majority of their readers are entirely at the mercy of the compilers. Those who read scientific books of a higher class are much more capable of taking care of themselves.

Professor Ansted's slip found its way into a scientific journal, where it was made the basis of a speculation. (See *Geologist*, 1861, p. 246.)

The most recent noteworthy inaccuracies connected with this famous Cavern are, so far as I am aware, two in the English edition of Professor N. Joly's *Man Before Metals* (1883).

According to the first, 'An entire left hind leg of *Ursus spelæus* was found lying above the incrustation of stalagmite which covered the bones of other extinct species and the carved flints' (p. 52).

It is only necessary in reply to this to repeat what has been already stated: All the bones of Cave-bear found in the Cavern were in beds *below* the stalagmite.

The following quotation from the same work contains the second inaccuracy, or, more correctly, group of inaccuracies, mentioned above: 'We may mention among others the cave at Brixham, where, associated with fragments of rude pottery and bones of extinct species, heaps of oyster shells and other saltwater molluscs occur, as well as fish-bones of the genus *scarus*' (p. 104).

I am afraid there is no way of dealing with this paragraph except that of meeting all its statements with unqualified denials. In short, Brixham Windmill-Hill Cavern contained no pottery of any kind whatever, not a single oyster shell, nor even a solitary bone of any species of fish. One common limpet shell was the only relic of a marine organism met with in the Cavern.'

As already intimated, the result of the researches at Brixham quickened a desire to re-examine the Kent's Cavern evidence, and this received a considerable stimulus from the publication of Sir C. Lyell's *Antiquity of Man* in 1863. Having in the meantime made a careful survey of the Cavern, and ascertained that there was a very large area in which the deposits were certainly intact, to say nothing of unsuspected branches which in all probability would be discovered during a thorough and systematic exploration, I had arrived at the conclusion that, taking the Cavern at its known dimensions merely, the cost of an investigation as complete as that at Brixham would not be less than 1,000*l*.

Early in 1864, I suggested to Sir C. Lyell that an application should be made to the British Association, during the meeting to be held at Bath that year, for the appointment of a Committee, with a grant of money, to make an exploration of Kent's Cavern; and it was decided that I should take the necessary steps in the matter. The proposal being cordially received by the Committee of the Geological Section, and well supported in the Committee of Recommendations, a Committee—consisting of Sir C. Lyell, Mr. J. Evans, Mr. (now Sir) J. Lubbock, Professor J. Phillips, Mr. E. Vivian, and myself (Hon. Secretary and Reporter)—was appointed, and 100*l*. placed at their disposal. Mr. G. Busk was added to the Committee in 1866, Mr. W. Boyd Dawkins in 1868, Mr. W. Ayshford Sanford in 1869, and Mr. J. E. Lee in 1873. The late Sir L. Palk (afterwards Lord Haldon), the proprietor, placed the Cavern entirely under the control of the Committee during the continuance of the work; the investigation was begun on March 28, 1865, and continued without intermission to June 19, 1880, the Committee being annually reappointed with fresh grants of money, which in the aggregate amounted to 1,900*l*.; besides 63*l*. received from various private sources.

The mode of exploration was essentially the same as that followed at Windmill-Hill, Brixham, but as Kent's Cavern, instead of being a series of narrow galleries, contained a considerable number of capacious chambers, and as the aim of the explorers was to ascertain, not merely what objects the deposits contained, but their exact position, their distribution, their condition, their collocation, and their relative abundance, the details had to be considerably more elaborate, while they remained so perfectly simple that the workmen had not the least difficulty in

carrying them out under my daily superintendence. The process being fully described in the First Annual Report by the Committee (see *Report Brit. Assoc.* 1865, pp. 19, 20), it is unnecessary to repeat it here.

Mr. Godwin-Austen, while agreeing with Mr. MacEnery that flint implements occurred under the Stalagmite, contended that they were found throughout the entire thickness of the Cave-earth. MacEnery, on the other hand, was of opinion that in most cases their situation was intermediate between the bottom of the Stalagmite and the upper surface of the Cave-earth; and, while admitting that occasionally, though rarely, they had been met with somewhat lower, he stated that the greatest depth to which he had been able to trace them was not more than a few inches below the surface of the Cave-earth. (*Trans. Devon. Assoc.* iii. 326–327). The Committee soon found themselves in a position to confirm Mr. Godwin-Austen's statement, and to say with h m that 'no distinction founded on condition, distribution, or relative position can be observed whereby the human can be separated from the other reliquiæ' (*Trans. Geol. Soc.* 2nd Ser. vi. 444).

Mr. MacEnery's 'Plate F' contains seven figures of three remarkable canine teeth, and the following statement respecting them: '*Teeth of Ursus Cultridens. Found in the cave of Kent's Hole, near Torquay, Devon; by Revd. Mr. McEnery, January* 1826, *in diluvial Mud mix'd with Teeth and gnaw'd Bones of Rhinoceros, Elephant, Horse, Ox, Elk, and Deer with Teeth and Bones of Hyænas, Bears, Wolves, Foxes, &c.*

It is worthy of note that no other plate in the entire series names the date on which the specimens were found, or the mammals with whose remains they were commingled. This arose probably from the fact, well known to MacEnery, that no such specimens had been found elsewhere in Britain; and possibly also to emphasize the statements in his text, should any doubt be thrown on his discovery.

It is, no doubt, unnecessary to say here that the teeth belonged to a large species of carnivore to which, in 1846, Professor Owen gave the name of *Machairodus latidens.* MacEnery states that the teeth he found were five upper canines and one incisor; and the six Museums in which they are now lodged are well known.

A considerable amount of scepticism existed for many years in some minds as to whether the relics just mentioned were really found in Kent's Cavern, it being contended that from its zoological affinities *Machairodus latidens* must have belonged to an earlier fauna than that represented by the ordinary Cave mammals; and various hypotheses were invented to explain away the difficulty, most of them, at least, being more ingenious than ingenuous. Be this as it may, it was naturally hoped that the re-exploration of the Cavern would set the question at rest for ever; and it was not without a feeling of disappointment that I had to write seven successive annual Reports without being able to announce the discovery of a single relic of *Machairodus.* Indeed, the greater part of the Eighth Report was written with no better prospect; when, while engaged in washing a 'find' met with on July 29, 1872, I found that it consisted of a well-marked incisor of *Machairodus latidens,* with a left ramus of lower jaw of bear, in which was one molar tooth. They were lying together in the first or uppermost foot-level of Cave-earth, having over it a continuous sheet of Granular Stalagmite 2·5 feet thick. There was no longer any doubt of MacEnery's accuracy; no doubt that *Machairodus latidens* was a member of the Cave-earth fauna whatever the zoological affinities might say to the contrary; nor was there any doubt that Man and *Machairodus* were contemporaries in Devonshire.

I cannot pass from this case without directing attention to its bearing on negative evidence: Had the exploration ceased on July 28, 1872—the day before the discovery—those who had always declined to believe that *Machairodus* had ever been found in the Cavern would have been able to urge, as an additional and apparently conclusive argument, that the consecutive, systematic, and careful daily labours of 7 years and 4 months had failed to show that their scepticism was unwarranted. Nay, more, had the incisor been overlooked—and, being but a small

object, this might very easily have occurred—they might finally have said '15·25 years' labour'; for, so far as is known, no other relic of the species was met with during the entire investigation. In all probability had either of these by no means improbable hypotheses occurred, geologists and palæontologists generally would have joined the sceptics; MacEnery's reputation would have been held in very light esteem; and—to say the least—his Researches regarded with suspicion.

When their exploration began, and for some time after, the Committee had no reason to believe or to suspect that the Cavern contained anything older than the Cave-earth; but at the end of five months, facts, pointing apparently to earlier deposits, began to present themselves; and at intervals more or less protracted additional phenomena, requiring apparently the same interpretation, were observed and recorded; but it was not until the end of three full years that a vertical section was cut showing, in undisturbed and clear succession, not only the Cave-earth with the Granular Stalagmite lying on it, but, under and supporting the Cave-earth, another, thicker, and continuous sheet of Stalagmite—appropriately termed Crystalline, and below this again an older detrital accumulation, known as the Breccia, made up of materials utterly unlike those of the Cave-earth.

The Breccia was just as rich as the Cave-earth in osseous remains; but the lists of species represented by the two deposits were very different. It will be sufficient to state here that, while remains of the Hyæna prevailed numerically very far above those of any other mammal in the Cave-earth, and while his presence there was also attested by his teeth-marks on a vast number of bones, by lower jaws—including those of his own kith and kin—of which he had eaten off the lower borders as well as the condyles, by long bones broken obliquely just as hyænas of the present day break them, and by surprising quantities of his coprolites, there was not a single indication of any kind of his presence in the Breccia, where the crowd of bones and teeth belonged almost entirely to Bears.

No trace of the existence of Man was found in the Breccia until March 1869, that is about twelve months after the discovery of the deposit itself; when a flint flake was met with in the third foot-level, and was believed to be not only a tool, but to bear evidence of having been used as such (see *Report Brit. Assoc.* 1869, pp. 201, 202). Two massive flint implements were discovered in the same deposit in May 1872, and at various subsequent times other tools were found, until at the close of the exploration the Breccia had yielded upwards of seventy implements of flint and chert.

While all the stone tools of both the Cave-earth and the Breccia were Palæolithic and were found inosculating with remains of extinct mammals, a mere inspection shows that they belong to two distinct categories. Those found in the Breccia—that is the more ancient series—were formed by chipping a flint nodule or pebble into a tool, while those from the Cave-earth—the less ancient series—were fashioned by first detaching a suitable flake from the nodule or pebble, and then trimming the flake—not the nodule—into a tool.

It must be unnecessary to say that the making of nodule-tools necessitated the production of flakes and chips, some of which were no doubt utilised. Such flakes, however, must be regarded as accidents, and not the final objects the workers had in view.

It is worthy of remark that in one part of the Cavern, upwards of 130 feet in length, the excavation was carried to a depth of 9 feet, instead of the usual 4 feet, below the bottom of the Stalagmite; and that while no bone of any kind occurred in the Breccia below the seventh foot-level, three fine flint nodule-tools were found in the eighth, and several flint chips in the ninth, or lowest foot-level.

It may be added that the same fact presented itself in the lowest or corresponding bed in Brixham Windmill-Hill Cavern. In short, in each of the two famous Devonshire Caverns the archæological zone reached a lower level than the palæontological.

That the Breccia is of higher antiquity than the Cave-earth is proved by the

unquestionable evidence of clear undisturbed superposition; that they represent two distinct chapters and eras in the Cavern history is shown by the decided dissimilarity of the materials composing them, the marked difference in the osseous remains they contained, and the strongly contrasted characters of the stone implements they yielded; and that they were separated by a wide interval of time may be safely inferred from the thickness of the bed of stalagmite between them.

It is probable, however, that the fact most significant of time and physical change is the presence of the Hyæna in the Cave-earth or less ancient, but not in the Breccia or more ancient of the two deposits. I called attention to this fact in a paper read to this Department ten years ago (see *Report Brit. Assoc.* 1873, pp. 209–214), and at greater length elsewhere in 1875 (see *Trans. Plym. Inst.* v. 360–375). Bearing in mind the Cave-haunting habits of the Hyæna, the great preponderance of his remains in the Cave-earth, and their absence in the Breccia, it seems impossible to avoid the conclusion that he was not an occupant of Britain during the earlier period.

The acceptance of this conclusion, however, necessitates the belief, 1st. That Man was resident in Britain long before the Hyæna was.

2nd. That it was possible for the Hyæna to reach Britain between the deposition of the Breccia and the deposition of the Cave-earth. In other words, that Britain was a part of the Continent during this interval.

Sir C. Lyell, it will be remembered, recognised the following geographical changes within the British area between Newer Pliocene and Historical times. (See *Antiquity of Man*, ed. 1873, pp. 331, 332.)

Firstly, a pre-glacial continental period, towards the close of which the Forest of Cromer flourished, and the climate was somewhat milder than at present.

Secondly, a period of submergence, when the land north of the Thames and Bristol Channel, and that of Ireland, was reduced to an archipelago. This was a part of the Glacial Age, and icebergs floated in our waters.

Thirdly, a second continental period, when there were glaciers in the higher mountains of Scotland and Wales.

Fourthly, the breaking up of the land through submergence, and a gradual change of temperature, resulting in the present geographical and climatal conditions.

It is obvious that if, as I venture to think, the Kent's Cavern Breccia was deposited during the first continental period the list of mammalian remains found in it should not clash with the list of such remains from the Forest of Cromer, which, as we have just seen, flourished at that time. I called attention to these lists in 1874, pointing out that according to Professor Boyd Dawkins (*Cave-Hunting*, p. 418) the Forest-bed had at that time yielded 26 species of mammals, 16 of them being extinct, and 10 recent; that both the Breccia and the Forest-bed had yielded remains of the Cave-bear, but that in neither of them had any relic or trace of Hyæna been found. A Monograph on the *Vertebrata of the Forest-bed Series* was published in 1882, by Mr. E. T. Newton, F.G.S., who, including many additional species found somewhat recently, but eliminating all those about which there was any uncertainty, said: 'We still have 49 species left, of which 30 are still living, and 19 are extinct' (p. 135). Though the number of the species has thus been almost doubled, and the presence of the Cave-bear remains undoubted, it continues to be the fact that no trace of the Hyæna has been found in the Forest-bed, and no suspicion exists as to his probable presence amongst the eliminated uncertain species.

It should be added that no relic or indication of Hyæna was met with in the 'Fourth Bed' of Brixham Windmill-Hill Cavern, believed to be the equivalent of the Kent's Hole Breccia.

I am not unmindful of the fact that my evidence is negative only, and that raising a structure on it may be building on a sandy foundation. Nevertheless, it appears to me, as it did ten years ago, strong enough to bear the following inferences:—

1st. That the Hyæna did not reach Britain until its last continental period.

2nd. That the Men who made the Palæolithic nodule-tools found in the oldest known deposit in Kent's Cavern, arrived during the previous great submergence, or, what is more probable—indeed, what alone seems possible unless they were navigators—during the first continental period. In short, I have little or no doubt that the earliest Devonians we have sighted were either of Glacial, or, more probably, of Pre-glacial age.

It cannot be necessary to add that while the discovery of remains of Hyæna in the Forest-bed of Cromer, or any other contemporary deposit, would be utterly fatal to my argument, it would leave intact all other evidence in support of the doctrine of British Glacial or Pre-glacial Man.[1]

Some of my friends accepted the foregoing inferences in 1873, while others, whose judgment I value, declined them. Since that date no adverse fact or thought has presented itself to me; but through the researches and discoveries of others in comparatively distant parts of our island, and especially in East Anglia, the belief in British Pre-glacial Man appears to have risen above the stage of ridicule, and to have a decided prospect of general scientific acceptance at no distant time.

I must, before closing, devote a few words to a class of workers who are 'more plague than profit.'

The exuberant enthusiasm of some would-be pioneers in the question of Human Antiquity results occasionally in supposed 'discoveries' having an amusing side; and not unfrequently some of the pioneers, though utter strangers, are so good as to send me descriptions of their 'finds,' and of their views respecting them. The following case may be taken as a sample. In 1881, a gentleman, of whom I had never heard, wrote, stating that he was one of those who felt deeply interested in the Antiquity of Man, and that he had read all the books he could command on the subject. He was aware that it had been said by one palæontologist to be 'unreasonable to suppose that Man had lived during the Eocene and Miocene periods,' but he had an indistinct recollection that another eminent man had somewhere said that 'Man had probably existed in England during a tropical Carboniferous flora and fauna.' He then went on to say, 'I have got that which I cannot but look upon as a fossil human skull. I have endeavoured to examine it from every conceivable standpoint, and it seems to stand the test. The angles seem perfect, the contour the same but smaller in size than the average human head; but that, in my opinion, is only what should be expected if we assume that Man lived during the Carboniferous period, in spite of what Herodotus says about the body of Orestes.' Finally, he requested to be allowed to send me the specimen. On its arrival, it proved, of course, to be merely a stone; and nothing but a strong 'Unscientific Use of the Imagination' could lead anyone to believe that it had ever been a skull, human or infrahuman.

It may be added that a few years ago a gentleman brought me what he called, and believed to be, 'three human skulls and as many elephants' teeth,' found from time to time, during his researches in a limestone quarry. They proved to be nothing more than six oddly shaped lumps of Devonian limestone.

So far as Britain is concerned, Cave-hunting is a science of Devonshire birth. The limestone caverns of Oreston, near Plymouth, were examined with some care in the interests of Palæontology as early as 1816, and subsequently as they were successively discovered. The two most famous caverns of the same county—one on the northern, the other on the southern shore of Torbay—have been Anthropological as well as Palæontological studies; and, as we have seen, have had the lion's share in enlarging our estimate of Human Antiquity. The researches have, no doubt, absorbed a great amount of time and of labour, and demanded the

[1] P.S. The announcement, in the *Geological Magazine* for October 1883, pp. 433–5, of the recent discovery of remains of the Cave Hyæna in the Forest Bed, renders it necessary to reconsider the bearing of the Kent's Cavern facts on the question of Pre-glacial Man in Devonshire.—W. P.

exercise of much care and patience; but they have been replete with interest of a high order, which would be greatly enhanced if I could feel sure that your time has not been wasted nor your patience exhausted in listening to this Address respecting them.

FRIDAY, SEPTEMBER 21.

The following Reports and Papers were read:—

1. *Report of the Committee for defining the Facial Characteristics of the Races and Principal Crosses in the British Isles.*—See Reports, p. 306.

2. *Report of the Anthropometric Committee.*—See Reports, p. 253.

3. *The Borness Cave, Kirkcudbrightshire. By* A. R. Hunt, *M.A., F.G.S.*

After referring to the published reports of the exploration of the Borness Cave (vid. 'Proc. Soc. Ant. Scotland,' vols. X., XI., XII.), and acknowledging his indebtedness to his colleagues on the exploration committee for permission to refer to the manuscript records of the cave work, the author proceeded to point out the peculiar interest attaching to the Borness Cave, from its position on the sea-coast, and from its having been resorted to as a place of refuge on more than one occasion previous to the period known as Romano-British. The three principal occupations of the cave were indicated by the following deposits, viz.:—(1) An upper deposit of dark cave earth, between three and four feet thick, of Romano-British age. (2) A thin band of charcoal, bones, and shells at the junction of the fourth and fifth foot levels. (3) A layer of charcoal and other organic remains sloping outwards from the interior at an incline of about 1 in 26. At the entrance of the cave the lower band (3) was separated from the Romano-British cave earth (which at this point thins out) by a deposit consisting of stones and carbonate of lime in different proportions, capped by pure stalagmite. Of this deposit, at the point indicated, some five feet at least must have been formed before the Romano-British occupation commenced. The era of the occupation indicated by the lower band was separated from that indicated by the Romano-British cave earth by the period represented by the intercalated mass of stalagmite and breccia. Without attempting to define the rate of deposition of the carbonate of lime at Borness, the author deprecated any assumption that it was necessarily rapid; the absence of limestone in the neighbourhood and the exposure of the stalagmite to the wash of rains, presenting conditions unfavourable for its rapid formation. The fact that the cave is on the sea-coast precludes the possibility that it was resorted to as a refuge from the Saxons, who had command of the sea long before they took possession of Galloway by land. The Romano-British occupation of the Borness cave may well have been earlier than that of the English caves that have produced implements similar to those from Borness, as the district in which the latter is situated was less firmly held by the Romans than those parts of Great Britain south of the wall of Hadrian. The author referred to the well-known bone implements which have been variously described as links, portions of musical instruments, and receptacles for bone pins. Owing to the fact that one specimen from Borness was solid, and that another, a hollow one, contained bone pins, the author felt unable to accept any of the current theories respecting these implements. He suggested that these objects might have been advantageously used as handles for imparting a rotatory motion to individual strands in the manufacture of leather ropes, the pegs fixed into a piece of wood being used to regulate the twist of the rope. The author exhibited a small three-strand leather rope made in the manner suggested.

4. *On the Relative Length of the first three Toes of the Human Foot.* *By* J. Park Harrison, *M.A.*

Last autumn, at Southampton, the author mentioned that a long second toe, though commonly met with in the works of Italian painters and sculptors, both ancient and modern, seldom occurs in unrestored feet of Greek statues.

Finding an impression prevalent that it was a natural or normal feature, he examined, in 1876, the feet of Scotch and Irish children at Glasgow, principally boys between nine and twelve years of age, when it was found that there was no tendency to the peculiarity in that part of the kingdom; and it was ascertained subsequently to be exceptional in adult males in Great Britain and Ireland generally. It is not unfrequently met with in female feet in England; and Dr. Pruner Bey found that it was common amongst Alsatian women. Possibly this may be owing to some peculiarity in shoes. A second toe longer than the first, or great toe, appears to have characterised the Umbrians and Etruscans; and it still exists in Italy amongst their descendants. This probably accounts for the excessive length of the second toe in Raphael's pictures. It is believed to have characterised the Carians and some other tribes of Asia Minor, and also one of the early Egyptian races.

The author thinks that the feature was not adopted by the ancient artists from any ideal motive, but always represented the native form of the foot. He mentioned that it was common in the Pacific and Peru, but was not a character of the lower races generally.[1]

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5. *On the Antiquity of Man in Ireland.* *By* W. J. Knowles.

The author stated that it was not acknowledged that any implements older than neolithic were found in Ireland, but lately he had found certain pear-shaped implements at Larne and other parts of the north-east coast of Ireland, which he believed to be not only older than neolithic, but far older even than palæolithic implements. They are more or less cylindrical in shape, and pointed, with a dressed butt for holding in the hand, and differ from palæolithic implements in not being flat with cutting edges. The author believed that the men who used these implements had a fixed idea of making pointed implements more or less cylindrical in form, just as the palæolithic people made flat pointed implements or the neolithic people implements with a cutting edge at the broad end. Part of them were obtained from gravels near Larne, and some at other parts of the north-east coast. One was obtained from boulder clay, and another fine implement was found having glacial markings on the chipped surface. The author showed some natural flint stones which, in his opinion, may have suggested the pear-shaped form, and he believed the palæolithic implements presented a further development of the same idea. Reference was made to Professor Boyd Dawkins' work, 'Early Man in Britain,' where he looks on the remains of the extinct mammalia found in Ireland, such as the mammoth, a tooth of which has been found near Larne, as 'the remains of a preglacial fauna which happen to have been preserved in spite of the erosion of the surface by glaciers.' The author was inclined to adopt this view, and was of opinion that the pear-shaped objects which he exhibited were the implements used in hunting this preglacial fauna.

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6. *On a Human Skull found near Southport.* *By* G. B. Barron, *M.D., L.R.C.P., M.R.C.S. Eng.*[2]

A few years ago, some workmen in making a deep cutting at Birkdale, near Southport, discovered a human skull, fifteen feet below the surface, lying on a bed

[1] See *Jour. Anthrop. Inst.* Part 3, vol. xiii.

[2] Published *in extenso* in the *Southport Visiter*, Sept. 22, 1883.

of laminated clay; the rest of the skeleton was not looked for, unfortunately. It had evidently been severed from the trunk by the planks driven down to prevent the sides of the trench slipping. In immediate proximity were found also the horns and bones of the great Irish elk, and, not far distant, abundant roots and trunks of forest trees, chiefly oak and ash, belonging to a submerged forest, no doubt co-extensive with the submerged forest known to exist along the Lancashire and Cheshire coasts. The skull was in a state of good preservation, being covered with a coating of peroxide of iron, deposited on it from percolation. It is now in the Museum of the Royal College of Surgeons, but a cast is exhibited.

A similar skull was discovered at Leasowe, some distance off, under similar geological conditions. These skulls are the only ones of the same type found in the North of England. They are identical with each other, and are dolicho-cephalic, orthognathic and aphanorygous, and they pertain to the Eskimo.

In the district surrounding Southport full evidence of an old submerged forest is to be found, and in it there can be no doubt the Irish elk and some other extinct animals lived and roamed.

Southport is built on the site of this submerged forest, of which there is abundant proof by the frequent exposure of trunks and roots of trees, buried at some depth below the surface, all lying on laminated clay, the trees having been cut down five or six feet above the roots. The geology of Southport and district is post-tertiary, so far as it has been tested, and remains in much the same state as left by the glaciers of the ice age, the action of which, all along the coast-line, has been that of deposition, accretion, and formation of moraines, with peat and drift-sand superimposed. The deluge theory of this submergence is not tenable. The author does not believe that a deluge ever touched this forest or this part of Europe.

Borings to a depth of 600 feet have only revealed sand-drift, marine-shells, alluvial peaty loam, peat, laminated clay, grey clay, and boulder clay, with stones. In some places the upper boulder clay, intercalated with sandy drift, lies on the Keuper marl. Erratics of Shap granite are very abundant in the boulder clay of the district, most of which are well scored. Elks' horns, as thick as a man's wrist, have been found, and *rough* flint heads and implements have been frequently met with. The village of Crossens, adjacent to Southport, stands on a heap of boulder clay, and fifteen feet below the surface is a bed of fine pebbles, &c., with water carrying sand.

A general subsidence of this coast has occurred, carrying with it the forest, when sea invasion took place, after which an upheaval came on, again elevating the land above the sea-level. This upheaval appears to be going on, although the relative levels of land and sea have not been materially altered for several thousands of years.

Taking the geological surroundings, and the entire absence of any other data to elucidate the antiquity or otherwise of these human remains, it can only be concluded that they belong to the period of the Cave Man. This opinion is strengthened by the fact that evidence of Cave man has been discovered in Cefn Cave, not very distant from Southport, across the estuary of the Mersey. That the Palæolithic hunter did inhabit the above cave, there is not a shadow of a doubt, and he had no other hunting ground than the forests of Flintshire, Cheshire, and Lancashire, which were continuous. It seems probable, then, that this man hunted in this great primeval forest, and the Irish elk was one of his quarries; that he died in it, and was submerged with it, and that he was a Palæolithic hunter, and had not human sepulture. But if not a Palæolith, he could not be later than the very earliest Neolith, before the latter was civilised, and before he had begun to use polished implements. There is, however, no satisfactory evidence to disqualify the opinion that he was a Palæolithic hunter.

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7. *On the Descendants of Cain.* *By* C. Staniland Wake.

After referring to the opinion that the great building-races of antiquity were Turanians, and that the civilisations of Chaldea, Egypt, and Phœnicia were traceable to a common source in Western Asia, facts were mentioned in support of the

belief that the civilisation of the Dravidians, who were the great architects of India, originated at the same centre. Reference was also made to the Turanian affinity of the Dravidians, and the existence among the ancient Chaldeans of a Turanian race, which possessed an advanced civilisation. This civilisation would seem, as supposed by M. Lenormant and other writers, to have been handed down from pre-deluge times to the Turanians, and to have been transmitted by them to the Hamitico-Kushites. Facts such as the invention of the arts of metallurgy and architecture were mentioned to show that the ancient Turanians were in reality Cainites, a conclusion which was supported by the consideration of social and religious phenomena. The pre-Deluge history of Genesis furnishes evidence of the existence of an hereditary enmity between the descendants of Cain and those of Seth, and also a difference of religion, such as afterwards subsisted between the Caucasian races and the Turanians. The prevalence of serpent worship among the latter was referred to, and reasons were adduced for believing that the people who erected the Naga Temples of Cambodia were allied to the pre-Aryan race of Northern India, with whom the Hindoo Pandavas were probably also connected. The peculiar development of serpent worship among the Egyptians and the Chinese, as well as its existence among the Hamitic and Turanian peoples generally, with the latter of whom it was probably a primeval superstition, was dwelt upon as further evidence of the affinity between those peoples. In conclusion, reference was made to a mark which is said to be found on the hip of every new-born Chinese child, and also to a similar mark mentioned by Mr. John Morris as distinguishing individuals belonging, as he supposes, to the true Hamitic stock, and it was suggested that the tradition as to the mark of Cain may be based on such a phenomenon.

SATURDAY, SEPTEMBER 22.

The Department did not meet.

MONDAY, SEPTEMBER 24.

The following Report and Papers were read:—

1. *Report of the Committee on the Investigation of 'Loughton' or 'Cowper's' Camp.*—See Reports, p. 243.

2. *On a Flint Implement found on Torre-Abbey Sands, Torbay. By* W. Pengelly, *F.R.S., F.G.S.*

On January 26, 1883, Mr. H. W. Watson, of Torquay, found a flint implement lying on the well-known submerged forest, Torre-Abbey Sands, Torbay, near the ordinary spring tide low-water line, and he was so good as to submit it to me. It is 4·8 inches long, 1·55 inch in greatest width, ·6 inch in greatest thickness, round at each end, but broader and thicker at one than the other; convex on one margin, but slightly concave on the other, ·3 inch thick at the broader end, and ·2 inch at the narrower. Its inner face is slightly concave longitudinally, and convex transversely, it has a slight 'bulb of percussion' near its broader end, and is nowhere smooth. The outer face is convex, and divided into two unequal slopes by a ridge inclining towards the convex edge of the tool. The abrupter slope has undergone a considerable amount of dressing; the concave edge is thin and comparatively sharp, while the convex edge has apparently seen some service. It does not apepar to have been rolled or scratched, and all the facts connected with it point

to its having been dislodged from the forest bed very shortly before the time, and very near the spot, on which it was found. There appears to be neither record nor tradition of any stone tools having been previously found under circumstances suggestive of a forest derivation in South Devon; but flint flakes and 'cores' have been met with in considerable numbers in the submerged forest of Barnstaple Bay, North Devon. An antler of red deer, fashioned into a rude but unmistakable tool, was found in the Torbay forest as long ago as 1852, and had thus prepared the mind for Mr. Watson's discovery. The same forest has yielded remains of mammoth, red deer, wild hog, *Bos longifrons*, and sheep, or goat.

3. *Three Golden Cups. By* Miss A. W. Buckland.

From three cups of gold of similar pattern, which have been found, one in Cornwall, one in Mycenæ, and one in the necropolis of ancient Tarquinia, Miss Buckland endeavours to show that some commercial intercourse must have existed between Mediterranean peoples and the British Isles during the bronze age, to which period the Cornish cup is assigned by antiquaries.

It is pointed out that the museum of Corneto-Tarquinia contains, in addition to the cup so strongly resembling that found in Cornwall, many other articles in gold, which have been classed with that cup by such competent authorities as Dr. Evans and Mr. Franks, and especially a *lunula,* and some of those articles, usually regarded as clasps, or as having been used as money, which are found in abundance in Ireland, *lunulæ* having also been found in Cornwall and Scotland.

Miss Buckland infers from these discoveries that Mediterranean races, and particularly the Etruscans, had established a commerce, and formed some kind of settlement in Ireland and perhaps in Cornwall, in prehistoric times, and points out that this is entirely in accordance with Irish legends, which invariably bring the heroes and founders of the nation from the shores of the Mediterranean. This prehistoric settlement, if established by further investigations, is looked upon as likely to clear up many obscure points in anthropology, archæology, and folk-lore; as barbarous races, then, as now, would naturally be slowly changed, and instructed in the arts of civilisation, by intercourse with those more advanced than themselves.

4. *On the Koeboes and other Tribes of Sumatra, and on some Customs prevalent among the Inhabitants of Timor. By* H. O. Forbes, *F.Z.S.*

The author, during five years' journeyings in the East, visited many of the islands of the Malay Archipelago—Java, Sumatra, Amboina, Aru, Kó, the Tenimber Islands (generally called Timor-laut), (vide Report of B.A. Committee, Section D, for the present year; and P.Z.S., 1873, February 20, April 17, May 1 and June 5), Boeroe and Timor. In Sumatra he visited, among other districts, the little-known people living in the plateau of the Passoemah Lands, who were described as pagans, having many curious customs; in this region he discovered several large stone images and sculptures, about which there appear to be no traditions as to their use, or by whom they were made, among the peoples of these lands, but which cannot be referred to the work of the Hindoos. Farther to the north, on the boundaries of the Djambi country, the author fell in with the forest-dwelling tribe of the *Koeboes,* supposed by some to be the remnants of the original inhabitants of the island. A short account of their habits was given, and a female cranium exhibited to the section. The author then passed on to give some account of the inhabitants of the Portuguese portion of Timor, through which, by exceptional privileges given to him by his Excellency Senhor da França, the Governor, he was able to travel. He described their customs relating to marriage, or *Barlaquè,* drawing special attention to the existence in some districts of husband-clans and wife-clans. He next referred to what appeared to be part of their religious ritual, known among them under the name of Loelik; and lastly, to their death-rites.

The author also drew attention to the supposed existence in Timor of a tribe of *Negritoes.*

5. *On the Cranial Characters of the Inhabitants of Timor-laut.* *By* J. G. Garson, *M.D.*[1]

The osteological remains received of the inhabitants of Timor-laut from Mr. Forbes's expedition consist of a series of eleven skulls and crania. Of these nine are adult, one is that of a youth of about twenty years of age, and one is that of a child. Four of the skulls are those of males, and six those of females. The skull of the child may belong to either sex. All except the skulls of one female and that of the child are broad in proportion to their length; the latter two are narrow in proportion to their length.

The average cranial capacity of the four male skulls measured according to Broca's method is 1,607 c.c., while the five round-headed females average 1,327 c.c. Compared with European skulls the average of the male skulls from Timor-laut is somewhat larger, while the size of the female skulls is smaller than those of Europeans. The difference between the size of the males and females is 280 c.c., while that between the two sexes of Europeans is 185 c.c.

The cephalic index, or the relation of the maximum length and the maximum breadth, varies little except in the long-headed skulls, in which the maximum length is greater and the breadth less than in any of the other skulls. The round skulls belong to Broca's class, true brachycephalic, except one of these skulls, which falls within the sub-brachycephalic class from its width being less than in the others, though the length is the normal. The long skulls both belong to the true dolichocephalic.

The height index is greater in the brachycephalic females than in the males by 2. In the dolichocephalic female the height index is much lower than in the brachycephalic, a condition which the late Professor Rolleston usually found to obtain in dolichocephalic skulls. The height of the skulls is in all instances except one less than the breadth.

The horizontal circumference of the male skulls averages 507 mm., and of the females 475 mm., while the transverse circumference of the former is 456 mm., and of the latter 424 mm.; between the two circumferences of both sexes there is a difference of 32 mm. The horizontal circumference of the dolichocephalic female is greater, while the transverse circumference is less, than that of any of the other females. The greater size of this latter skull is owing to the anterior segment being largely developed.

One of the male skulls is orthognathous, the other skulls of both sexes are mesognathous, except one male skull, which is just within the prognathous group, and the dolichocephalic female, which is prognathous.

From the orbital index averaging 85·1 in the males and 84·7 in the females, both belong to the mesoseme group as regards the form of the orbit.

The form of the nasal aperture varies. The males are on the average at the platyrhine end of the mesorhine group, while the females are just within the platyrhine group.

The chin is somewhat rounded and less pointed than in Europeans.

Flattening of the occipital or parieto-occipital region exists in almost all the specimens, but in some it is more marked than in others. The forehead is well formed, without prominent ridges. The nasal region is flattened, but the degree of flattening seems to vary in different individuals.

The result of the observations of the osteology of the people shows that we have two distinct racial elements amongst these, namely the Malayan and the Melanesian. The former is represented by the brachycephalic skulls, which are the more numerous, the latter by the dolichocephalic skulls.

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6. *Yassin and the Kajunah District.* *By* Dr. R. G. Latham.

Its early area was probably larger than it is at present. Probable evidence is to be found in the Chinese *Han* annals, as translated by Mr. Wylie, and to some

[1] This paper will appear *in extenso* in the *Jour. of the Anthrop. Inst.*, part 2 of the vol. for this Session.

extent edited by Mr. Howorth, in the 'Transactions of the Anthropological Institute,' date A.D. 1, both before and after. The Chinese name is '*Wosoon*'; the area corresponds with that of the '*Issedones*' of Herodotus. If this be the case a new light is thrown over the early ethnology of Kashgar, the parts about *Ili* or Kuldja, and the Galcha country.

7. *On the Words Celt, German, and Slavonian, their Misinterpretation, and its Results. By* Dr. R. G. LATHAM.

Of these three names the first is as old as Herodotus, the second dates from the time of Julius Cæsar, the third is no older than the seventh century A.D.

The term *Slave*, *Sklave*, *Sclavonian*, &c., is, according to the strong conviction of the present, no definite name at all, but a word like *Tra*montane in Latin, and *za*-gora, za-*volok*, i.e. *beyond the mountain* and *beyond the watershed*, in Slavic. If so *za*-laba would be *over the river* (or water), and as such would be applicable to any portion of the area which we now call Sclavonic. Hence it is not a national name at all, though, at the same time, when we know what it means and what it does not mean, it is a convenient one—convenient because in the words like *Panslavonism* we find it recognised.

There is no great misrepresentation here, and *Slavonic* as a word is connected with *Celt* and *German*, not for what it represents, but for the extent to which it is *mis*represented.

This brings us to a point of some importance: (1) If the Celtic area of antiquity was as large as it is supposed to be, there was no such being as a Slavonian *south* of the Danube; (2) and if the German area was so large as it is supposed to be, there would be no Slavonism to the *north* of that river. Instead of them we should have Celts to the south, and no Germans to the north of that river—practically no area larger than the county of York, of which Slavonians were occupants; indeed, from a certain point of view there would be no Slavonians in Europe till about A.D. 600, when they present them in force both to the south and the north of the Danube, especially in the districts which ten years before were assigned to the Celts and Germans.

From this comes the question, 'Whence come the Slavonians? and whither went the Celts and Germans?

This and the answer to it is the question which the present writer investigates, not, of course, in full detail, but sufficiently to indicate the amount and character of what he unwillingly calls the *mis*interpretation of two classical authorities, or rather the *mis*interpretation of *Tacitus* in the case of the Germans, and the *neglect* of a special statement in *Ephorus*, as preserved by Strabo, in regard to the Celts.

8. *On a Pile Dwelling recently discovered at Ulrome, in Holderness, Yorkshire. By* JAMES W. DAVIS, *F.S.A.*, *F.G.S.*

Formerly a great part of Holderness was covered by a series of lakes and meres, only the slightly hilly parts being elevated sufficiently to form dry land. Some years ago the country was drained artificially, and during the operation Thomas Boynton, Esq., of Ulrome Grange, discovered some implements and fragments of wood which had apparently been used as piles. In consequence of these discoveries Mr. Boynton was led to excavate one of the sites, and found that it had been pierced about midway in making the drain. A space about 20 yards square has been cleared and the plan followed in the construction of the dwellings is clearly exposed. The base of the structure is formed by a number of large trunks of trees, several being 18 inches in diameter; these were laid horizontally on a bed of peat about 2 feet in thickness, which being superimposed on a bed of gravel, in all probability formed the bed of the lake. The tree-trunks are held in position by a number of pointed stakes, driven into the peat beneath, on each side the trunks. The stakes or piles have been cut by a very rude implement, probably the stone adzes or axes found associated with the remains of the buildings. The

horizontal timbers were laid apparently without any definite arrangement, and the spaces between them were filled up with broken twigs, bark, and the chippings cut from the piles, until a level surface was obtained above the surface of the water of the lake. On this the builders probably erected their domiciles, though no trace of them remains at the present time. Above the surface of broken twigs and bark there has been an accumulation of 3 feet of peat and about 1 foot of warp and soil, so that the base of the dwelling is about 6 feet above the bed of the ancient lake, and 3 to 4 feet below the present surface of the ground, the whole being about 10 feet in thickness. During the excavations numerous objects have been found which throw light on the habits of the people who erected and occupied the dwellings—rounded stone implements, probably used for pounding grain, stone axes and hammers, worked smooth and pierced for the introduction of a handle. Several large bones, probably the femur or humerus of the cow, have been broken in two diagonally across the shaft, and a hole drilled through near the joint, into which a stick was inserted, forming implements which may have been used for breaking up the land. The antlers of the red deer were in all probability used for a similar purpose, and several have been found. Numerous pieces of pottery have been discovered; they are of a British type. A single bronze spear-head has been found, and a few examples of flint implements.

It may be inferred, from the remains found during excavation and the character of the portion of the dwellings which remains, that the people were devoted to agricultural pursuits, that the dwellings were erected a short distance from the edge of the lake for protection against wild animals rather than for defence against human foes, and that their implements of bone were well adapted for working in the light sandy or warpy soils which occupied the higher ground rising from the border of the lake.

TUESDAY, SEPTEMBER 25.

1. *The Influence of Town Life on Stature.* *By* J. PARK HARRISON, *M.A.*

From a comparison of the average stature of the population in towns of 5,000 inhabitants and upwards with that of pure country folk in the British Isles, the Anthropometric Committee in 1881 found that town life affects stature to a far less extent than had been before supposed.

The author has extracted from the tables in the above Report the average stature of artisans in towns of the ages of twenty-five to thirty-five, and those of country labourers of the same age; on comparing them, the difference is 0·92 inches in favour of the country folk.[1]

Stature has been found to be low in Bristol;[2] but if the average stature of the inhabitants of that town is compared with that of the nearest county from which there are a sufficient number of observations—viz. Somersetshire—then the respective statures are found to be 5 feet 5·77 inches and 5 feet 6·30 inches, the difference being ·53, on 300 and 447 observations. It is therefore probable if a larger number of observations of stature from Edinburgh and Glasgow were obtained, the average stature in those cities would prove to be higher than 5 feet 6·35 inches.

The stature of the townsfolk in Sheffield is low, not so much, apparently, owing to town life, as the unhealthy occupation of the population; and lastly, London, where the stature, from 259 observations, comes out higher than that in Herts, Middlesex, and Surrey, but slightly lower than Essex or Kent,[3] requires far more extensive returns before any safe conclusion can be arrived at regarding the average stature of the inhabitants.

[1] The term includes railway guards and porters.
[2] Report Anthropometric Committee, 1883. [3] *Ibid.*

Since it is probable that many persons physically unfit for country pursuits find employment in towns, they may perhaps contain a larger proportion of the descendants of the short dark race called Iberian, than rural districts.

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2. *Anthropometry.* *By* J. G. Garson, *M.D.*

The methods of measuring the human body, whether it be the living subject or the skeleton, have been so diverse that the results obtained by one observer can seldom be utilised and extended by another: each anthropologist using more or less different measurements. That a general understanding be come to, so as to obtain one system which would be universally used, is very desirable. Two measurements, both of great importance, will be dealt with in this communication; these are the measurements of length of the skull and of its capacity.

The length of the skull has been taken as (1) the length between the nasion and the most distant part of the occipital bone in the mesial line; (2) the distance between the most prominent parts of the glabella and the occiput; and (3) the length between the ophryon and the most distant part of the occiput. The first measurement of length has only been used by a few anthropologists in Germany, and as it has not found much favour may be discarded, especially as it is not one that recommends itself. The second method has been perhaps the most generally adopted on the Continent. It is the maximum length of the skull, and can be ascertained with ease and accuracy, alike on the living subject and on the skull, a matter of great importance. It has been usual to measure the length of the head in the living in this way, and the only objection that can be urged against its being adopted also for the skull is that the glabella includes the frontal sinuses, which are liable to vary in size and prominence. The ophryo-occipital length has usually been adopted in this country, and the advantages claimed for it are that it does not include the air sinuses, and that it represents more accurately the length of the brain. Its disadvantages are that the ophryon is not a definite point, but will be placed higher or lower on the frontal bone by different observers; the frontal bone being curved, the length of the skull will vary according to the position of the point considered as the ophryon. The adoption of the one or the other of these measurements should depend upon its relative advantages. The advantages of the ophryo-occipital length appear to be more apparent than real, as in any case it is only a very approximate estimate of the length of the brain that can be obtained from it, owing to the different thicknesses of different skulls both in the region of the ophryon and occiput, while the disadvantage of its being uncertain, owing to different points being fixed as the ophryon by different observers, is a very serious objection to it. The glabello-occipital measurement of length appears to the author to present greater advantages and less disadvantages than the ophryo-occipital. He therefore thinks that the former should be adopted universally as the length measurement, not only of the skull, but also of the head of the living subject.

The capacity of the skull would be best ascertained by filling it with water or mercury, and then measuring the quantity used for that purpose. This is not possible, however, from its porous and irregular character, not to mention its numerous foramina. We have, therefore, to resort to the use of solid substances. For this purpose sand has been used, but is now abandoned as not being satisfactory. Filling the cranium with mustard seed, and gently rolling it backwards and forwards and from side to side at intervals during the process, was practised by Mr. Busk, but has likewise not been found satisfactory, owing to the results obtained being uncertain, and the capacity indicated being less than the actual capacity. Shot was used by Morton, but with indifferent success. It was not until introducing the maximum quantity of shot or seed was practised that more certain results were obtained. Professor Flower modified Mr. Busk's method with mustard seed by tapping on the skull while the seed was being introduced, and again whilst the quantity which had been got into the cranium was being ascertained by pouring the seed into a graduated glass vessel, the seed being run into the skull and into the measuring glass through the same funnel. This method, while

equalising the process of filling the skull and ascertaining its cubage, is open to the serious objection that the quantity of seed which can be introduced into the skull, and likewise the space it will occupy in the measure, depends upon the amount of tapping practised. There being no means of regulating this, the result obtained depends upon the observer. Variations to the amount of 25 to 40 c.c. are not unfrequent in different measurements of the capacity of one and the same skull by the same observer. Broca, some years ago, introduced a system of measuring the capacity with shot, according to a method whereby the measurer is made to play a secondary part, the accuracy being dependent upon the system which has been minutely described in his work on craniology. By this system the skull is filled as full as possible with shot of a given size, according to certain directions which he gives. The quantity which has been introduced into the skull is then measured in glass vessels according to a fixed plan. The results of this method show that the variations between different manipulations on the same skull do not vary more than from 5 to 10 c.c., any greater variation than this occurring indicates that some error has been made in the process. The advantages of this method at first sight appear to be very great, but unfortunately the results obtained from it are somewhat greater than the actual capacity such as would be obtained by filling the cranial cavity with fluid. This error is, however, a relative one, and can be corrected by ascertaining how much the capacity measured with shot is greater than the actual capacity. This can be done by careful measurement of some test skulls rendered impervious to fluids, with shot, and water or mercury. Notwithstanding its disadvantage in this respect, the author thinks Broca's method is the most trustworthy and the best one for estimating the capacity, and would therefore recommend its adoption.

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3. *A new Method of comparing the Forms of Skulls.* *By* W. S. Duncan.

The author brought forward a new method of comparing the forms of skulls so as to bring out their relative characters by the superposition of their outlines. Outlines in profile had first to be made full-size from the actual skulls; marking the basion, the alveolar point, and the glabella or the nasion very carefully, then drawing the basi-alveolar line and dropping a perpendicular to the latter from the glabella or the nasion. All the skull outlines must then be re-drawn to suit a common standard height of the glabella, or of the nasion, above the basi-alveolar line; that is, the perpendicular from the glabella (if that point be used) must be the same in all the outlines to be compared, or the perpendicular from the nasion (supposing that point is preferred), must be of the same length in all the series—without altering the shape of any one skull, or the relation of its parts to one another in position or size; which is easily done by means of proportional compasses.

Then tracings are made of each of the skull-outlines thus assimilated in the height of glabella or nasion above the basi-alveolar line, and they are placed over each other so that the basi-alveolar line in each shall coincide in position, and so that the perpendicular drawn thereto from the glabella or from the nasion shall entirely coincide.

Top views or plans must be made by drawing outlines projected upon a plane parallel to the basi-alveolar line, and end views upon a plane perpendicular to the basi-alveolar line.

As the result of such treatment the author exhibited outlines of two species of Orang, *Simia satyrus* and *Simia morio*, which were by this method clearly seen to illustrate the law that a diminished prognathism was accompanied by increased cranial development. The same truth was illustrated by profiles of skulls of a chimpanzee and a gorilla superposed; by those of two chimpanzees superposed; by outlines of a Fijian and an Australian skull superposed.

The author further applied the method by the superposition of an orang's skull-outline over the outline of the skull of an Andamanese, and contrived intermediate stages of jaw-reduction and cranium-expansion so as to indicate the type of the ancestral forms of the Andamanese skull. Without alleging that the ancestors of the

Andamanese were orangs the author contended that they were probably orang-like in the breadth of the brain-case compared with its length, for, omitting the ridges on the side of the orang skull, the skull of the orang and that of the native Andaman islander were both brachycephalic: and both were, in the region of the glabella, remarkably smooth, and devoid of brow-ridge as compared with other types of human and ape-skulls.

A series of nine link outlines thus deduced were exhibited, in which the author had allowed a decreasing rate of jaw-reduction for equal degrees of cranium expression.

The author observed that link 1, in his Orang to Andamanese series, corresponded in length of jaw to *Simia morio*, but that the cranium of the latter was relatively more developed. This, together with similar facts, he showed indicated that greater progress may have been made in the increase of cranium than in the reduction of the size of the jaws in the bygone evolution of the human skull, so that, in looking for links, isolated jaws may have been ape-like in dimensions while belonging to well-developed crania; similarly, isolated crania may have had considerably ape-like jaws associated with them, though the crania are to all appearance those of human proportions.

In the same manner links were deduced between the chimpanzee and Australian types of skull, in which prominence of brow ridge and dolichocephale were associated. This the author admitted was no proof that the ancestors of Australians were chimpanzees, but merely indicated that they were probably intermediate in typical form.

Outlines of the Neanderthal calvarium and of an Irish calvarium in the Phrenological Museum of Edinburgh were superposed upon an Australian skull outline, with the result of diminishing the importance of the Neanderthal calvarium as respects inferiority of development; the Irish being smaller in all respects than the Neanderthal calvarium. But inasmuch as the calvaria in question were so fragmentary, it was impossible to indicate with any approach to exactness the type of the facial portion that must have belonged to these skulls originally.

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4. *Local Science Societies and the minor Pre-historic Remains of Britain.*[1] *By* R. Meldola, *F.C.S.*

This paper, which was first read at the Conference of Delegates from local societies, and had been referred by the Conference to the Anthropological Section in order to give it greater publicity, contained some suggestions which the author had first put forward in his presidential address to the Essex Field Club. The author proposed that all the local societies throughout the country should co-operate in the production of a complete catalogue of all the prehistoric remains of Britain, giving their position, external form and structure, and bibliographical references. He further suggested that the various local societies should form prehistoric monuments committees, for the purpose of drawing up the catalogue, and at the same time conducting, if possible, actual explorations of all doubtful remains. These local committees would also act as vigilance committees, keeping watch upon all the ancient remains in their neighbourhood, and preventing as far as possible their destruction. In cases where, through building or agricultural operations, demolition is unavoidable, the author suggested that the local societies should appoint watchers to record the presence of any relics that might be found. The author stated in conclusion that the neglect of such opportunities by local societies in past times had led to the loss of a vast amount of evidence which might have been of the greatest importance to anthropology, and he urged upon local societies the adoption of a useful line of work which would necessarily increase the efficiency of Sir John Lubbock's Ancient Monuments Bill.

[1] Published *in extenso* in *Nature*, Nov. 1, 1883, p. 19.

5. *The Yahgan Indians of Tierra del Fuego.* By HYDE CLARKE.

The author stated that, in consequence of the publication by Lady Brassey of the 'Voyage of the *Sunbeam*,' great attention had been paid to these Indians by men of science here and in Germany. On examination of the language he found that its relations were of a distinct character with a group in Africa, and with the Ngoten, &c., particularly. This raised an important question as to the mode in which the language had been transmitted to the extremity of South America.

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6. *Primitive Astronomical Traditions as to Paradise.* By R. G. HALIBURTON.

The author had met with a great mass of primitive legends among savages as to a primæval paradise, with its Tree of Life and of Knowledge, being situated in the stars of Taurus, the Pleiades. As far back as 1863 he privately printed a paper entitled 'New Materials for the History of Man, derived from a comparison of the Calendars and Festivals of Nations.' In the course of these astronomical researches, he had met, to his surprise, with curious traditions as to a Paradise and deluge, the cross, a tree or bough, and a bird connected with the primitive year and its festivals. He had since devoted much careful study to this enigma, and the present paper gave only a portion of these investigations, for the subject was too wide to be outlined in a paper. Half a century ago, many learned works were devoted to coincidences in the religious ideas, traditions, and symbols of nations; and it was by some supposed that they were distorted vestiges of the sacred narrative, but this view had been abandoned, and all these learned investigations had been discredited. We now cut the Gordian knot, which we cannot solve, as to these common traditions and beliefs, and suppose them of indigenous growth. But, while this conclusion might, in many instances, be right, there were many coincidences too arbitrary and widely spread to admit of the solution that the beliefs and religious ideas of primitive races were all the emanations of darkness, stagnation, and decay. The author then selected some American traditions as to the Tree of Life and Paradise. The symbols of a cross and a bough or tree, he thought, were suggested by the form of the Pleiades, which when they set have a remarkable resemblance to a prostrate tree. The Kiowas of the prairies believe that in the shape of the Pleiades and of some adjoining stars can be seen the form of their great Father in Heaven, the great Kiowa. Once upon a time he went far to the West and met with a prostrate tree or trunk which he struck three times. At the first stroke human beings of misshapen, monstrous forms came forth. These he put to rights, placed them back in the tree and struck it a second time, when perfect men and women came forth from this tree of life. He placed them again in the tree, and struck it a third time, when men and women and children that had been born, came out of it. He instructed the men and women in the rude arts of savage life, and then went up to the Pleiades. This belief in our having sprung from a tree is well known in the Old World, in Britain, Lapland, Germany, Greece, Persia, and other countries. An Indian tribe of the Pampas, the Abipones, believe that their Great Father resides in the Pleiades, and when these stars disappear from the heavens for a time, it is believed that he dies or is ill, and when those stars reappear his revival is hailed with joy. This gives a clue to the death and revival of the gods of antiquity. These people use the symbol of those 'stars of rain,' the prehistoric cross, as an ornament or sacred sign. There is also a curious tradition of seven giant brothers, who fished off the west coast of Canada. They struck a huge monster with a harpoon. As the rope could not be loosened, they were dragged far into the ocean towards a vast whirlpool. Just as they neared it, the rope broke, and they sailed up to the Pleiades, where they are now visible as the seven stars. These seven brothers give us a clue to the seven Cabeiric brothers, of Phœnician tradition, who sailed in the first ship, and who have been identified with the Pleiades by Movers. But the story of the whirlpool is especially important, for we meet it in the traditions of the Dyaks of Borneo,

some of the ancestors of whom, as they were sailing in a boat, saw near a great waterfall the boughs of a tree touching the waters, and loaded with fruit. A Dyak climbed up the tree to see where its roots grew. He found out the enigma which is described in the Song of Odin, who hung nine days from a mystic tree, 'of which no one knows where its roots grow.' The Dyak reached a heavenly country, 'the land of the Pleiades, where he was taught agriculture, and other arts, by a kind being who dwells there, and then, bringing with him from the Pleiades the gift of rice or corn, he was let down by a rope from the seven stars, and imparted to his countrymen the mystic lore which he had learned by climbing that tree of knowledge.' This waterfall recalls the waterfall of the river Styx, and the whirlpool of the Haida tradition; also the whirlpool of Scylla and Charybdis, over which hung a great fig tree. A great number of interesting points were adduced connecting the primitive traditions of the natives of America and Polynesia with those of the Old World. The three Graces were, among the Iroquois, three loving sisters in the Pleiades, the spirits of the bean, the squash, and maize, their gifts to mortals. They are called 'Our Life, our Supporters'—the very words addressed to the spirit of agriculture in Mexico, and to this day in the Atlas country. The Lycian women of old invoked the bull to come and bring the Graces with him; and the bull of the mysteries is represented with the three Graces on its head, and the Pleiades following them. This referred to the constellation Taurus, or the bull, in which the Pleiades were placed. When 'the bull with its white horns opened the year,' it brought, all over the world, a kindly New Year's feast of family love. Even among the head-hunting Dyaks of Borneo, Bishop Chalmers was asked on New Year's Day to go out to the assembled people and to give them his wishes for a happy New Year. In many parts of the world it is followed by visits, gifts, and good wishes. This is one of the oldest and most universal festivals.

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7. *Personal Names and Tribe-Names of the Gaels.* *By* HECTOR McLEAN.

The following is a summary of the subjects treated by the author in this paper:—

Personal names of pure Gaelic origin; tribe-names or surnames derived from them; explanation of the meanings of several of them; comparison of some of them with old Gaulish personal names and tribe-names. *Mac*, son, descendant in an extended sense, placed before personal names and the names of various vocations to form family names; mutation of the initial consonants of the names following *Mac*; attraction of the *c* of Mac to names following it beginning with a vowel. *O'* = *Ua*, grandson, descendant in an extended sense, not found in Scottish Highland Gaelic names, the Duke of Argyll and his clan excepted, who have the surname *O'Duibhne* (O'Duin) besides Campbell. Tribe-names occurring in Adamnan's 'Life of St. Columba;' Anglicising of Gaelic personal names and surnames; Scripture and classical names introduced among the Gaels with Christianity; Scandinavian names introduced among them with the Scandinavian invasions, commencing in the eighth century. English names introduced into Ireland by the English conquest; Lowland Scotch names introduced among the Gaels of the Highlands. Confusing of names, such as Godfrey with the Gaelic *Guaire*, Samuel with *Somhairle* (Somerled), Livingstone with *Dunlevy*, Johnstone with *MacIain* (John's son), Eachann (Ecken) and *Eachthighearn* (Eckern) with Hector.

WEDNESDAY, SEPTEMBER 26.

The following Papers were read:—

1. *The Polynesians and their Origin.* *By* C. STANILAND WAKE.

The paper mentioned various facts showing that the physical features of the Polynesians, although often European, allied them rather to the Mongolian than to the Caucasian stock. This opinion was confirmed by reference to various mental

and social characteristics, which appeared to connect them with the Taranian peoples of India. Mr. Fornander's theory of a pre-Vedic Aryan origin for the Polynesians was considered, and it was suggested that a Dravidian origin for them was more probable. This view agreed with the opinion expressed by Mr. Keane as to a connection between the Polynesians and the Khmêrs of Cambodia, seeing that, as the paper showed, the Khmêrs were settlers from Upper India, and probably Dravidians, more or less Aryanised. Their occupation of Cambodia would lead to a movement among the native inhabitants, many of whom fled to the Indian islands. A similar movement would appear to have taken place at a later period during the era of *Wakea*, a chief of Gilolo, about the first century B.C., when the migrations of the Polynesians over the Pacific began. They doubtless, however, followed in the footsteps of peoples belonging to the same stock, a tradition of whose voyages would be handed down to the Polynesians.

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2. *The Germanic and Rhœtian Elements in Switzerland.* *By* JOHN BEDDOE, *M.D., F.R.S.*

The anthropology of Switzerland has been much studied, and to a great extent disentangled, by His and Rütimeyer, Dunant, Guillaume, Kollmann, Studer, and the investigators of the lake-dwellings. The author had lately visited the eastern part of the country, and collated with his personal observations what these authors have stated as to the stature, colour, and head-form of the people.

The Swiss, or at least the eastern and central Swiss, speaking for the most part High Dutch, used to be reckoned with ourselves as a Teutonic people. There is, however, one strong objection to be taken to a system of classification of European peoples which ranks together the English and the Swiss. The head-form of the former is distinctly long, and that of the latter short and broad. The English form may be called by some orthocephalic, or mesocephalic, or mesaticephalic, but it certainly inclines pretty decidedly to the long end of the scale. Dr. Barnard Davis, in his 'Thesaurus,' puts the mean index of longitude at 76 or 77: probably about 77 is correct. Now His and Rütimeyer assign a breadth-index of over 86 to their typical Disentis skull, and ascribe to the Disentis type the majority of modern Swiss heads. I am not aware that anyone has ventured to state an average index for Switzerland; but such average would evidently be somewhere very far beyond 80, as is the case in most, if not all, of the surrounding countries, as Savoy, Bavaria, Tyrol, and, in a less marked degree, even Würtemberg and Lombardy.

On the other hand the distribution of colours among the Swiss does not differ very notably from that which obtains among the English. One might be transported from Zürich to London, or *vice versâ*, without noticing anything in the complexions of the people to remind one of the fact. Nor are the prevailing features by any means so different from those of the English as is the usual form of head.

The results of the official examination of the colours of hair and eyes in the Swiss schools accord fairly well with the idea that the light complexion invaded the country by crossing the Rhine from Swabia into Aargau, and thence radiating through the central cantons, but fining down considerably before reaching the eastern and western frontiers. Putting the Celtic Helvetii for the moment out of the question, this is what might be expected to remain as the evidence of the Allemannic and Burgundian invasion. But, as we have reason to believe that both the Allemans and the Burgundians were long-headed as well as light-haired, we might reasonably expect to find a longer head geographically accompanying the lighter complexion. And so, probably, it does, but not so conspicuously as might have been looked for. The point has not, so far as the author is aware, been worked out by Swiss anthropologists with the detail which it merits.

While welcoming the gigantic masses of statistics respecting colour of eyes and hair which have been given us through the exertions of Virchow, Vanderkindere, and Kollmann, the author has always insisted on the necessity of remembering the im-

portance of the personal equation. When, therefore, he finds in Dr. Kollmann's tables that the little canton of Nidwalden has very many more light-haired children than any other one, he looks on the figures with some degree of suspicion. Partly for this reason he visited Stanz, the interesting little capital of Nidwalden, noted the colour of the people he met, and measured twenty skulls in the bone-house. He also took observations of the hair and eyes in Zürich and in Ticino and in several parts of the Grisons, measured thirty-six skulls in the ossuary of Davos, and some in that of Disentis, as well as a few living heads in both these places.

He reserves the somewhat dry details for another place, only mentioning, with regard to colour, that he found the index of nigrescence, which measures the predominance of dark over light shades of hair, to vary as follows:—

Nidwalden	22
Zürich	27
Basel	44
Davos	46
Prättigau	54
Central Grisons	56
Val Blegno	60
Disentis and Ober-Rheinthal	72

This scale corresponds fairly with the supposed proportion of Allemannic blood. Davos is more Germanic than most part of the Grisons; the valley is said to have been colonised by the German-speaking people of Upper Wallis.

As for the form of the heads, the Disentis type, more or less modified, seems to predominate even in Nidwalden and Davos; he found the latitudinal index exactly alike in both these places, viz. 83·6. He was somewhat surprised to find it so great in Nidwalden, where a great many of the inhabitants are blond and blue-eyed, and have a decidedly Saxon-English type of features.

There is more of light hair and blue eyes in the upper valleys of Ticino than in the Ober-Rheinthal, where Romantsch is spoken. Contrary to his previous opinion, he is now inclined to recognise there notable remains of Lombard blood.

The Disentis people are very interesting. It was not without reason that His and Rütimeyer gave the name to the broad-headed type. These Disentis folk exhibit in the highest degree the combination of dark hair with short, broad skulls. A typical living specimen, whom he was enabled to measure through the courtesy of Dr. Condrau, had an index of 88, which in the skull would be equal to about 90. He found a skull which yielded 92, and believes he could easily have found more extreme examples. Even allowing something for the flattening of the infant head by its being laid on the back, this is very remarkable. And the concurrence of the maximum depth of colour (usually very dark grey or light brown eyes with very dark brown, seldom coal-black, hair) seems to indicate clearly what was the colour of the aboriginal Rhætian race.

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3. '*Krao*,' *the so-called Missing Link.* *By* J. Park Harrison, *M.A.*

The conviction that the hairy child lately exhibited at the Aquarium in Westminster possessed ape-like peculiarities, which she had inherited from wild parents in some remote forest in Laos, appeared to be so widely entertained that the author thought it well to bring the subject before the Anthropological Department. Unfortunately an admirable description of the case by Dr. Garson, which appeared in the 'British Medical Journal' on July 6, 1883, was not copied into any of the daily journals or scientific periodicals, and so met the eye of only a limited class of readers. It showed that there was nothing abnormal in Krao, except the excessive hairiness; and this, from a recent letter from Siam, where it appears the child was born of slave parents, was not inherited from them, since they are said to exhibit no similar development of hair.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—Lieut.-Colonel H. H. GODWIN-AUSTEN, F.R.S., F.G.S., F.R.G.S.

THURSDAY, SEPTEMBER 20.

The PRESIDENT delivered the following Address:—

MY predecessor, Sir Richard Temple, selected for the subject of his address to this section last year 'The Central Plateau of Asia,' and he treated it not only from a broad and general geographical, but also, and to some extent, a political and historical point of view. Following him, in a measure, over some of the same ground, I have selected the mountain region south of the Central Asian highlands—viz., the Himalayas, and more particularly the western portion of that range, as the subject of this paper. I propose considering this mountain chain with reference to its physical features, past and present; and consequently with reference to its geological history, so far as that relates to later tertiary times—*i.e.* the period immediately preceding the present distribution of seas, land, rivers, and lakes. It is not, however, my intention to enter very deeply into the purely geological branch of the subject.

Comparatively little of the earth's surface now remains unexplored, but much remains to be surveyed and examined in a more scientific manner. Within the last fifty years explorers have made known to us the general features of those dotted or blank spaces which, as boys, we used to look at in our school atlas sheets with so much curiosity, mingled with no little desire to discover the hidden secrets of the unknown lands so shown. The student of the present day enjoys information more or less accurate respecting countries which to us were mere speculative shadows.

But there are other atlas sheets beneath, and only a very few feet beneath, those of this present day, which are closely connected with the latter, and beneath them again others lie still deeper which have modified the geography of this earth over and over again. It is to such a sheet or two relating to the great Himalayan chain that I now invite your attention. If we wish to deal with physical geography (and to my mind it has equal charms with either pure geography or exploration) our inquiry must, if we wish it to be of any really scientific value, be based on geological structure. We must study the ancient atlas sheets, one by one, which nature is, day by day, revealing to us by the denudation of the present surface, taking away and building up the material for atlas sheets of future epochs. Geography and geology are very intimately related; each is truly based upon the other. Local changes of temperature on the surface of this earth, and internally the slow shrinking of its crust, have effected gigantic changes of its surface, and are still altering the topographical features of every country. Directly we look back in time and space and note what changes have taken place, the science of geology steps in, and with it mathematics, chemistry, botany, and zoology. A raised sea-beach with its dead shells, or a submerged forest with the remains of its former fauna and flora, geologically an event of yesterday, sends us back thousands of years into the past, thinking of what were the aspect and dimensions of the former land; therefore,

to be a good geographer, something should be known of geology and its kindred sciences. This will be my excuse if in this address I dip somewhat below the surface, and, as some may think, introduce too much geology into this section. The basis, however, of this branch of knowledge is geography, and this the Royal Geographical Society and the British Association in this particular section do all they can to foster. There is no gainsaying the fact that very many of our ablest men of science, the ablest naturalists and geologists this country has produced (and it has taken a leading part in geology), have commenced their careers in connection with geographical exploration. Darwin's earlier studies were prosecuted whilst he was attached to marine surveys in other parts of the world; through the same school passed Huxley and Edward Forbes. There was no better example of an able geographer and geologist than Sir Roderick Murchison, who for years took a leading part at these meetings. The list might be largely extended—Sir Joseph Hooker, Wallace, Wyville Thomson, Moseley, &c. That most seductive of all studies, the geographical distribution of species, is intimately connected with geographical exploration. Just as the navy owes much of its efficiency to our coasting and mercantile marine and to our hardy fishermen, so have geography and other sciences been strengthened by the labours of those practical and scientific men who have been engaged in marine or territorial surveys.

The Himalayas, the highest mountains in the world, have excited the interest of many travellers and many geographers; very much has been written about them, some from personal knowledge, and a good deal on second-hand information. Much confusion has resulted from the features of the north-western area being so dissimilar in composition to those of the rest, or eastern part, of the chain, and the limitation placed on the breadth and extent of the whole as a mountain mass. There has been a tendency to apply the term 'Himalaya' in too extended a sense: it should, I consider, be restricted to those portions which dominate the plains of India, from the inhabitants of which country we have derived the name. This would, strictly speaking, apply only to the snowy range seen from the plains of India bordering upon the course of the Ganges; but we might, I think, use the term in an extended sense, so as to include, that which we may call the north-western Himalaya, north of the Panjab, and also the eastern Himalaya, bordering on Assam.

The orography of this mountain mass has been recently ably handled by Messrs. Medlicott and Blanford,[1] and I follow them in all their main divisions and nomenclature, which are based upon a thorough understanding of the rocks of the country. Some line must be selected where the term Himalaya in its widest sense must cease to be used, and this certainly cannot be better defined than by the valley of the Indus from Attock to Bunji. On this line we find the great bending round or change in the strike of all the ranges. Strictly speaking, the change commences on the south, where the Jhelum River leaves the mountains, but this line, north of Mozufferabad, continues on into the above-mentioned part of the Indus valley. To the mountains north of the Indus on its east and west course the name Himalaya should certainly never be applied. For this north-west Trans-Indus part of the Asian chain we have the well-known name Mustagh, so far as the head of the Gilgit valley; the Hindu Kush being an excellent term now in common use for its extension to the Afghan country.

The observations made by many of the assistants of the Indian Geological Survey, more especially by Stoliczka, and more recently by Lydekker[2] in the Himalayas, combined with those made by myself in the same region, have, when considered in conjunction with the ascertained strike of the granitoid or gneissic rocks, led me to separate the great Central Asian chain into the following five principal divisions, with some minor subdivisions:—

Central Asian Chain.[3]

1. The main axis or Central Asian, Kuenlun
2. Trans-Himalaya
3. Himalaya
4. Outer or Lower Himalaya
5. Sub-Himalaya

[1] *A Manual of the Geology of India*, 1879, p. 9. [2] *Memoirs of the Geology of India.*
[3] Consult Atlas sheets of the Indian Survey, 1 inch = 4 miles, and latest map of 1883.

I use the word 'chain' in its widest meaning, so as to comprise the whole length and breadth of a mountain mass, and not, as it has been sometimes used, to describe a 'chain' or single line of mountain peaks.

I show these and the equivalent ranges of other geographers and authors in the accompanying synoptical form; and if sections be made, at intervals of about 100 miles apart, through the whole mass of the chain from the plains of India to Thibet, they show where the different ranges are locally represented, and how they separate or are given off from the main axis lines. The same scale for both vertical and horizontal measurements should be used, because there is nothing more misleading than sections in which an exaggerated vertical scale is used. In our present state of ignorance as to the composition of the chain eastward from the source of the Sutlej, we cannot attempt to lay down there any axis lines of original elevation. The separation by Mr. Clements Markham[1] and Mr. Trelawney Saunders[2] of the line of highest peaks into one range, and the water-parting into another, is an acceptable solution of the physical features as at present known of this part of the chain. I am led to think, however, that when this ground is examined it will resolve itself into a series of parallel ridges more or less close, and oblique to the line of greatest altitude as defined by the line of high peaks, crossing diagonally even the main drainage line of the Tsang-po,[3] just as we see the Ladak axis crossing the Indus near Hanlé, or the Pir Panjal that of the Jhelum. Sir Henry Strachey's conception of the general structure was the soundest and most scientific first propounded.[4] He considered it to be made up of a series of parallel ranges running in an oblique line to the general direction of the whole mass, the great peaks being on terminal butt-ends of the successive parallel ranges, the watershed following the lowest parts of the ridges, and the drainage crossing the highest, in deep gorges directly transverse to the main lines of elevation.

It will be seen from sections, drawn as above, that the mountain mass of the Himalayas increases gradually in height from the south to about its central portion, and then as gradually falls towards the north side. There is no abrupt and conspicuous slope from the higher line of peaks to the plains; a succession of spurs from the main waterparting intervenes, and these spurs retain often a very considerable altitude far to the south. The spurs terminate, usually, abruptly towards the plains of India, at an altitude of 5,000 to 8,000 feet, just within a more or less broad belt of fringing low hills, the well-known Sivaliks.

It has been laid down that the Himalayan chain culminates in two parallel ranges running through its entire length from the Indus to the Brahmaputra, and these have been called the north and south Himalaya, or central and southern; the two combined (they are very close in parts) really constitute the above chain. We can apply this system to certain portions of the range, but it breaks down when we reach the Sutlej on one side and the Monass on the other. The more we increase the scale of our maps, the greater the number of axial lines we can establish, all intimately connected with, and subsidiary to, the run or strike of the greater series of axial elevations.

Explanation of the Different Ranges.[5]

1. *Kuenlun Range.*—The most westerly extension of this granitoid axis is found W.N.W. of the Zangi-diwan pass at Oikul and the Victoria Lake. Here

Turkestan and the countries between the British and Russian dominions in India—1 inch = 32 miles. Compiled under the orders of Lieut.-Gen. J. T. Walker, C.B., R.E., F.R.S.

[1] *Thibet.* Boyle and Manning. Introduction.

[2] *Geographical Magazine*, July 1877, p. 173.

[3] 'Tsang-po, Tsanpu, Sangpo, Sánpú—of different authors.

[4] 'Physical Geography of Western Thibet,' *Royal Geographical Society's Journal*, vol. xxiii. p. 2.

[5] The secondary ranges are not to be understood as being invariably true axis lines of elevation, but rocks of sedimentary origin on the flank, N. or S. of such main

		North-western Himalaya	Western Extension	Eastern Extension	Dr. Thomson, 1847-48	General Cunningham, 1854	Markham, 1876	Trelawney Saunders, 1877	Medlicott and Blanford, 1879
Tibetan Region	A. Main axis or Central Asian	1. Kuenlun	Great Pamir near Siri Kul Lake	Yeshil Kul on Aksaichin	—	—	—	—	Kuenlun
	—	2N. Karakoram	—	Compass La, Linggi Thang, &c.	—	Karakoram	Northern main range (western section) in part	Karakoram—west	Mustagh
	B. Trans-Himalaya	2. Mustagh	to the Baroghil pass and Hindu Kush	by Rudok to Aling Gangrhi Peak	—	Trans-Tibetan or Bolar	Northern main range (western section) in part	—	—
	—	2S. Shayok	Raki Pushi Peak	to Kailas Peak	—	—		Karakoram in part, Kailas or Gangrhi	—
		3. Ladak	North Deosai and Gilgit	to Gurla Peak, probably towards Fotu-La, but country beyond unknown	—	Kailas or Gangrhi in part	Northern main range (western section) in part	Northern chain of Himalaya in part at Gurla Peak	Ladak
		1N″. Stock	Kargil	Hanlé	—	Trans-Himalaya	—	Northern chain in part north of Spiti	—
		1N′. Rukshu	Dras and Gures?	Leo Purgial Peaks	—				
		4N. Baralasa	Suru	Parang-la, north of Chini Nilang to Niti passes	—		Central main range	Northern chain in part	—
	C. Himalaya			Rotang pass to Chini, Gangotri, Dhaolagiri, &c.	Trans-Sutlej	Western or Great Himalaya	—	Southern chain in part at Chini	Zaskar in part Himalaya
		4. Zaskar	to South Deosai & Nanga Parbet	—	—	—	—	Northern chain in Zaskar Southern at Chini	—
		4S. Chenab	Hoksar pass, cross Sind valley to Haramuk and Khagan to Palas	Rotang Pass	—	—	Southern main range	Southern chain in part, South of Chenab	—
Himalayan Region	D. Outer or Lower Himalaya	5. Pir Panjal	Kajnag, Manserah, to Sufeid Koh?	Chatadhar, Dhaoladha Chor, Nag Tiba to Almora	Cis-Sutlej in part	Mid-Himalaya in part The outer Himalaya or Dhaoladhar	— —	Southern chain in part —	Zaskar in part, Pir Panjal & Dhaoladhar
	E. Sub-Himalaya	6. Sivalik ridges	Attock and Kalabagh	Miri Hills, Assam	—	—	—	—	Sub-Himalaya
Terai		—	—	—	—	—	—	—	—
Plains of India		-	—	Assam Valley	—	—	—	—	—

Stoliczka records it[1] with slates and schists resting on it to the southward. Now the next great granitoid axis south of the above, with palæozoic rocks on its northern face, is at the Mustagh pass, fifty miles to the south of the Kuenlun at Zangi-diwan, and it coincides in position with the gneiss of Kila Panza,[2] the granitic axis of the Mustagh being continued W.N.W. in the high peaks of Hunza-Nagar. The Kuenlun axis passes by Shahdula eastward by peaks E. 61, 23,890, E. 64, 21,500, up to Yeshil-Kul on the Keria route, for a distance of about 450 miles; beyond this is unexplored country.

I have adopted the term Mustagh as one well known to the people on both sides of the range, and better known than Karakoram, applied by them to the pass of that name. The Karakoram pass also lies on an axis of elevation further to the north and intermediate between the Mustagh and Kuenlun.

2. *Mustagh.*—This axis, as I have shown above, commences near Kila Panza in Wakhan, thence by the Baroghil and Kerambar passes to the great peaks dominating the Hunza valley to the Mustagh pass, eastward by K_2 28,250, to the great peaks north of the Shayok, K_9, K_{10}, K_{11}, K_{12},[3] the Sassar pass, and thence S.E. on to the Marse Mik La and the high mass north of the Pangkong Lake, crossing at Nyak Tso on to the high range south of the Rudok plain, where we again enter unsurveyed ground. It is probably continuous to the Aling Gangri, the old original drainage of the Shayok passing through it at the Pangkong Lake, thus repeating in a similar way that of the Indus through the Ladak range near Hanlé. This most remarkable depression of the whole area, the Rudok plain, lies S.E. of the Pangkong Lake, where, on the same meridian as the sources of the Indus and Tsang-po, we have a plain only a little above 14,000 feet, which once drained in glacial and preglacial times into the Shayok, rendering that branch as long, probably longer than the present Indus. From a high point above the Pangkong I have looked over this plain; for a distance of some sixty miles it was seen bounded to the south by mountains of over 21,000 feet, and no mountain ranges broke the horizon. The depression is a broad and continuous one here, lower and more extensive than that at the head of the Indus. It is not improbable that it indicates the head waters of the next great drainage area north of the Indus, viz., of the rivers that find an exit to the sea through Burmah. The Gang-rhi and Karakoram, or Mustagh, cannot be therefore considered as one range separating the Indus basin from that of the northern or central plateau of Thibet. This must lie across the broad elevated plateau that extends from the Karakoram pass, having a general parallelism to the Kuenlun certainly so far as 34° N. and L. 82° E.

The crystalline limestone near the west end of the Pangkong Lake would appear to be the same as the similar limestone at Shigar near Scardo. It comes in, too, on the north side of the great gneissic axis, the northern boundary of which follows the Shayok River pretty closely from Tanksé and Shayok to Khapalu. The foldings in the gneiss which have caught up the palæozoic slates near Tanksé are again on the west indicated by the metamorphic schists on the Indus south of Kartaksho, and by those in the section S.W. of Scardo.

2N. *Karakoram-Lingzi Thang Range.*—West of the pass the country is not known. Eastward the line of elevation passes north of the Dipsang plain to the Compass La, and south of the Lingzi Thang plain, by the Changlung Burma La to the neighbourhood of the Kiang La, and thence still further east it may pass north of Sarthol into Garchethol.

3. *The Ladak-Gurla Range.*—This is the best defined, as a continuous granitoid

lines; the result of the original elevation, and subsequent denudation. In a strictly geographical sense these must be indicated—especially where they have any considerable extension, or become a noticeable feature of the country—as, for instance, the relative position of the Baralasa ridge to the Zaskar, a portion of the main Himalaya.

[1] *Scientific Results of the Yarkand Mission*, p. 38.

[2] Stoliczka, *loc. cit.* p. 38.

[3] Unknown and unnamed peaks were thus designated during the progress of the triangulation.

axis, on the east and west of Leh; the Indus flows at the base of its escarpment for 190 miles, and this line also was not far from the limit of the ancient nummulitic sea. On the west it unites with the great plateau of Deosai and extends to Gilgit. The Indus drainage has cut through it from south to north into the Scardo basin, and back again to south at the sharp bend at Bunji, while on the east at Haulé the same river passes to the north again, and the range is continued following the left or south bank up to the Gurla peak, south of the Mansarowar Lake. Thence it is probably continuous up to the Fotu La.

2S. *The Shayok-Kailas.*—This subsidiary axis is well marked on the south of the Pangkong Lake N.W. and S.E. of Tanksé, running parallel to the Ladak range. It is then to be followed westward, north of the Shayok River to the junction of the Basha Braldoh Rivers, and thence to Haramosh and Raki Pushi peaks, and perhaps through Yasin to Tirich Mir on the Hindu Kush. To the eastward from Sajam peak, the north side of the Indus and Gartangchu to the Kailas peak, thence very probably north of the head waters of the Brahmaputra.

4. *The Zaskar Range.*—Where best displayed, it is that portion which lies south of the districts of that name in Ladak, and runs parallel for 100 miles with the upper sources of that large tributary of the Indus, the river of the same name. In the size of the present glaciers, that fill the upper valleys, this portion more closely resembles the Alps of Europe than any other part of the Himalayan chain. It is continued to the N.W., past Dras, to the southern side of the Deosai plains, thus coalescing with that great elevated mass of the primitive rocks. It is continued to the Nanga Purbet, 26,620 feet, and it probably continues still further, west of the Indus, the curve of the range bounding Swat and Bajaur on the north towards Kunar, and which, after the central portion, we may term, at present, the Bajaur range. Taking it up in a S.E. direction, it bends slightly south, crossing the head of the Bagha River by the Rotang pass to that line of lofty snowy peaks seen from Simla and other hill stations leading past Chini to the east of the Sutlej, to the famous peaks of Gangotri, Nandadevi, and Nampa. To the majority of Europeans who have visited India this is perhaps the best known portion of the Himalayas.

4N′. *The Rukshu Ridge.*—Two secondary ranges, more or less connected with the last, one intimately so with an axis of trappæan intrusion of early tertiary age, which from Dras to the Mansarawa is over 400 miles in extent, can be followed. The first is conspicuous at the Tsomorirhi Lake, Mata Peak, 20,600 feet, being of granitic rock; it is seen on the west covered by the earlier sedimentary formations, but it can be traced towards Dras, and on the S.E. to the Imis La, curving thence towards the Leo Purgial mass, the elevated tertiary formations of Hundes coming in on the east.

4N″. *The Stok.*—Another subsidiary and later line of elevation, one I had at first been inclined to disregard in this address, being a minor feature in comparison with the whole chain, flanks conspicuously (attaining the very considerable elevation of over 20,000 feet) the left bank of the Indus for 200 miles, and is still more intimately related to the above trappæan intrusion. It forms a connecting link with the tertiary rocks of the same age on the southern base of the Himalayas (the elevation of which led on successively to the formation of the outermost range of hills, the Sivaliks), and shows the relatively recent date of the elevation of the whole chain, and the obliteration of the topographical details of a previous mountain mass.

4N. *The Baralacha Ridge.*—This line corresponds with the run of the highly tilted slates, carboniferous and succeeding formations, resting against the Zaskar axis, which it follows from near Suru to south of Padam by the Baralacha and Parang passes; here, for a short distance constituting the water-parting between the Indus and Chandrabagha, it can be traced towards the Sutlej, Chini, crossing on to the Keobrang, and in turn the Nilang, Niti, Lakhur, and Tinkar passes, displaying all along this line its characteristic feature, first seen at the Baralacha pass, of being the main waterparting between the Ganges and Kali basins on the south, and the Indus on the north, and constituting from here to the eastward, with the peaks on the granitic or gneissose axis, the main Himalayan range. In the Nipal area to the eastward, we notice the great similarity with

which one river basin follows the other, the only difference being that the watersheds of some lie further to the north than others. We may thus, I think, infer that the above character of the Baralacha axis is the type of the physical features along this unsurveyed, little-known territory, until we reach the longitude of Darjiling.

4s. *The Chenab and North Kashmir.*—South of the Chenab River, running parallel with it for many miles, is another gneissic axis, through which the Chenab passes into a sharp bend to the south near Kishtwar; the peak of Gwalga well marks its position here, and the strike of the same rock is continued towards the northern outer hills of the Kashmir valley by Barrapatta and Dalwas Peak, near the Hoksar pass, and the Maro Wardwan valley below Ainshin. For some distance the stratified rocks only are seen, but on the Boodpathar ridge near Srinagar and in the Sind valley, and again from near Haramook Peak to Tragbul, the gneissic rocks appear. Further still they occur in the hills at the head of the large tributaries of the Kahmil River, and thence I suspect are continued across the Kishengunga to the Snowy Peaks above Wamba and into Khagan. On the S.E. at the Rotang pass at the head of the Beas valley it unites with the Zaskar axis.

5. *The Pir Panjal-Dhaoladhar Ridge.*—On the outer face of the chain there is a well-marked gneissic or granitoid axis of elevation. It is well exemplified on the Dhaoladhar ridge above Dharmsala, directly connected with, and equally well displayed in, the Chatadhar ridge south of Budrawar; thence it can be traced to the Chenab, which breaks through it here, to the south-east side of the Kashmir valley, forming the eastern end of the Pir Panjal range. We find it at intervals amidst the older slates along the ridge westward, and close up to the gorge of the Jhelum River, where it leaves the valley of Kashmir. It reappears on the other side of the Jhelum in the Kajnag ridge towards Mozufferabad. The gorges of the Kishengunga and Khagan Rivers are near this place, and to the westward the granitoid rocks are again met with at Manserah in the Hazara valley. Little is known of the mountains to the north of this, but the axis apparently crosses the Indus near Amb, curving round in the Yusufzai Hills north of the Peshawar valley, the Sufedkoh being an analogous range on the south of the Kabul River. Returning to the Dhaoladhar ridge, the granitoid axis continues to Sultanpur on the Beas across that river, by Suket to Hatu, across the Sutlej to Kuper and Kanchu Peaks, and the well-known peak of the Chor. Nag Tiba, north of Mussoorie, would mark its eastern extension, beneath the slates of that ridge, and beyond Dudatcli and Binsar Peaks, and Almora to the Kali River,[1] near Meenda Ghur. This axis thus holds the same position with regard to the plains of India and at about the same distance from their base for a very great distance.

6. *The Sub-Himalaya.*—This longitudinal section of the Himalaya is easily defined by the fringing line of hills more or less broad, and in places very distinctly marked off from the main chain by open valleys (dhuns), or narrow valleys parallel with the main axis of the chain.

The Eastern Himalaya.—In Western Bhutan, beyond Darjiling, between the Juldoka and the Am Mochu, the gneissic rocks have a N.W. strike by the Pango La, apparently towards Kanchinjunga; to the S.E. by Betso Peak to the Singchula above Buxa. Hooker records Kinchinjhow as of granite, with stratified rocks to the north. This axis may possibly be continued E.S.E. to Chumularhi and the gneiss of the mountains north of Paro.

In the far east, in the Dafla Hills, a more general parallelism of the ranges from W. to E. is found, assimilating to the N.W. area. A well-marked granitoid axis is to be traced from S.W. to N.E. (the outer Himalaya here), convex to the S.E., the tertiaries or the Sub-Himalaya being of considerable breadth and elevation, and following the same curve. Considerable valleys or dhuns are also again a feature on this side.

Lastly, there is the Assam range, which, although not forming a part of the Himalayan mountain system, I must allude to, as I shall have to refer to it further on. This is very clearly defined by a gneissic axis on its southern margin, against which the secondary rocks rest, and by a more northern line of the same primitive

[1] Captain R. Strachey, R.E. 'P.G.S.' vol. vii. p. 292, 1851

rock, succeeded by another of isolated low hills following the northern base and the course of the Brahmaputra, and generally lying to the north of it. The last outcrop is seen at Dhoobri, and thence it is no doubt continuous across the delta to similar outcrops of Bengal gneiss on the Ganges, thus connecting this axis of elevation with that of peninsular India. The above range is convex to the south, curving up to the N.E. in the Lhota Naga and Nowgong Hills, and to the W.N.W. in the Garo Hills.

The Burrail range forms another subsidiary line of elevation to the above from the Naga Hills to Jaintiapur, and falls away dipping under the Sylhet *bhils*,[1] to reappear at the most S.W. point of the Garo Hills. From its highest point in the Naga Hills (Japvo), where the strata become nearly horizontal, it merges into and throws off the high N. and S. ridges that bound the Munipur valley on the west, to join the Lushai Hills on the south. This I would call the Western Munipur and Arakan range. It has no granitoid axis; but to the N.E. of Munipur a great mass of intrusive rock occurs at the high peak of Shuruifurar, and thence a high line of elevation runs N.N.E. to Saramethi Peak, and to the south forms the eastern boundary of the Munipur valley, and might be called the eastern Munipur range. It is the water-parting between the above valley and that of the Kyangdweng.

We can, in a measure, exemplify the structure of the Himalaya by that of the bones of the right hand, with fingers much elongated and stretched wide apart, of which the wrist and back may represent the broader belt of granitic rocks of the eastern area, the thumb and fingers the more or less continuous ridges of the N.W., some less prolonged than others to the north-west, such as the Chor axis, which may be represented by the thumb, terminating on the southern margin near the Sutlej. The left hand placed opposite will represent the same features to the west of the Indus. We will even carry this simile further, and as a rough illustration suppose the intervals or long basins between the fingers to be filled with sedimentary deposits, and the fingers then to be brought closer together, producing a crushing and crumpling of the strata. At the same time an elevation or depression, first of one or more of the fingers, then of another or of the whole hand has taken place, and you are presented with very much what has gone on upon a grand scale over this vast area. As these changes of level have not taken place along the whole range from E. to W. in an equal extent, but upon certain transverse or diagonal lines, undulations more or less great have been the result, and some formations have attained a higher position in some places than in others, producing, very early in the history of these mountains, a transverse system of drainage lines, leading through the long axial ridges.

The last efforts of these rising, sinking, and lateral crushing, and, as I believe, very slowly acting forces, are to be seen at the southern face of these mountains in the tertiary strata that make up the Sub-Himalayan axis (Sivalik), a topographical feature which is most striking by reason of its persistence and uniformity for some 1,600 miles; for, although a similar and synchronous elevation of the Alps has taken place, the same regularity of orographical features has not been the result, most probably from the difference in the original outline of deposition in the latter area. One object in this address will be to endeavour to point out and compare some of the physical features of the two great European and Asiatic chains.

From Assam on the east to the Panjab on the west, bending round and extending to Scinde, this fringing line of parallel ridges is found at the base of the Himalayas, sometimes higher, sometimes wider, often forming elliptical valleys. Only in one part of the belt east of the Teesta are they absent altogether, and for a distance of fifty miles the metamorphic rocks rise directly from the plains of India,[2] a feature representing a great break—the correct interpretation of which will tell us very much of the past history of these mountains. These formations are of vast thickness, and in the Panjab, where they attain their greatest width and elevation between the Chenab and the Indus, cover an area of 13,000 square miles.

[1] '*Bhil*' or '*jhil*'—Hind., a marsh.

[2] Godwin-Austen, *J. A. S. B.* 1867, p. 117. *Memoirs of the Geological Society of India*, Medlicott, vol. iv. pp. 392 and 435.

The whole of this material has been derived from the adjacent Himalayas, representing many feet of the older and higher mountain ranges, and has travelled down valleys that had been excavated in pre-tertiary times. This points to a slow subsidence of the whole southern side of the mountain mass, deposition generally keeping pace with it, broken off by recurring long intervals of re-elevation. Such important, well-marked features as these cannot be omitted when treating of a mountain system. Many long and instructive pages of its history are written on these rocks, with the help of which we may reconstruct some of the outlines of its more ancient geography.

The next most interesting feature connected with the former distribution of land and sea is that these Sub-Himalayan formations are fresh-water, or torrential, showing that since nummulitic or eocene times the sea has never washed the base of the Himalayas.[1] In fact, there is no evidence of this from the gorge where the Ganges leaves the mountains up to the base of the Garo Hills; pointing to an extension northward at that early age of the Arabian Sea, separated from the Bay of Bengal by peninsular India. I am led also to believe that from Assam to Scinde there once existed one continuous drainage line, a great river receiving its tributaries from the Himalayas, partly a land of lakes and marshes, the home of that wonderful mammalian and reptilian fauna which Cautley and Falconer were the first to bring to light. In pliocene times, before the greater displacements commenced, it is not unlikely that the Kashmir basin drained at the north-west end into the Kishingunga Valley to Mozufferabad, and that of Hundes and Ladak trended towards the same direction *viâ* Dras.

The southern boundary of this long alluvial plain was formed by the present peninsula of India, and probably of the extension of the Garo and Khasi Hills westward to the Rajmahal hills.[2] Depression has been considerable in the neighbourhood of Calcutta,[3] nearly 500 feet. We know probably only a portion of the alluvial deposits. At 380 feet beds of peat were passed through in boring, and the lowest beds contained fresh-water shells; the beds also were of such a gravelly nature as to indicate the neighbourhood of hills, now buried beneath the Ganges alluvium. This is precisely the appearance of the country above Calcutta on approaching the present valley of the Brahmaputra. The western termination of the Garo Hills sinks into these later alluvial deposits, and along the southern face of the range up to Sylhet, the waters of the marshes[4] during the rainy season wash the nummulitic rocks like an inland sea, and point to the very recent depression of all this area. The isolated granite hill-tops jutting up out of the marshy country from Dhoobri to Gwalpara and on to Tezpur all testify to the same continuous depression here. It is exactly north of this that we find the Sivalik formations absent at the base of the Himalayas, and we have the evidence of exclusively marine conditions in pliocene times at the base of the Garo Hills.[5] We find also a large development of marine beds above the nummulitic limestone in the Jaintia country,[6] passing up conformably into a great thickness of upper miocene sandstones of the Burrail range. In such sandstone north of the Munipur valley the only fossils I found were marine forms.

This gradual depression of the delta of the Ganges, the relative higher level of the water-parting and shifting of the Panjab rivers westward, appear to be only the last phase of that post-pliocene disturbance which broke up the Assam Sub-Himalayan lacustrine system draining into the Arabian Sea. Zoological evidence which I cannot here find space to quote is also in favour of this former connection of the now separated waters of the Ganges and Indus basins, and the hill tracts of the Garo and Khasi Hills with peninsular India.

The ground where the miocene rocks are absent is not where any denuding force from the north could have acted with any abnormal intensity. It lies under the hills where no great tributary enters the plain, and might have removed the

[1] Blanford and Medlicott, *Memoirs of the Geological Society of India*, p. 393.
[2] *Loc. cit.* p. 31. [3] *Loc. cit.* p. 397.
[4] For a very excellent account see Hooker's *Himalayan Journals*, pp. 263–265.
[5] Colebrooke, *Geological Transactions*, vol. i. p. 135.
[6] H. H. Godwin-Austen, *J.A.S.B.* 1869, pp. 12 and 152.

above formation. All the evidence is in favour of the axis line of depression in the Ganges delta between Rajmahal and the Garo Hills extending thus far, and that the miocene beds, once continuous, are here thus lost to sight beneath the more recent yet extensive gravels and conglomerates that here occur, and have partaken also of a last slight elevation of the mountain chain.

Even if we were to raise the rocks below the delta up to the maximum level of the Garo Hills, about 4,000 feet, it would not be a greater alteration of level than we can see now a very few miles distant to the east. The base of the cretaceous formation rests on granite at the peak of Kailas, about 3,000 feet above the sea; at thirty miles eastward it is at the level of the plains of Sylhet, scarcely removed above that level; it is here we find a remarkable depression right across the Assam range from north to south, which it is curious to note faces immediately the Monass valley of the Bhutan Himalaya.

Great lateral rolls or waves of the stratified rocks occur at intervals all along the southern line of the chain, and apparently have a connection with the transverse drainage lines. This feature is best seen if we follow the older miocene along its junction with the older rocks. The miocene attains its greatest elevation at Bisari and Keeran Peaks—11,200 feet—close to the end of the Pir Panjal axis; it falls thence towards Mari to 7,000 feet, and much lower towards the Potwar. Eastwards it is reduced, above Poonch, to 9,900 feet; near Rajaurie to 7,000 feet, and Kamrot 6,700 feet—or a fall of 4,500 feet in fifty miles. The elevation increases again, upon the Chenab, to 8,000 and 9,500 feet; and, facing the Chatadhar ridge, it is again of great elevation—9,096 feet at Hato Peak, and Mandhar 8,932 feet. At the Ravi, by Basaoli, there is a depression, east of that river, to 4,600 feet, but it gradually rises again to 6,100 feet at Dhurumsala, under the Dhaoladhar ridge, and retains that altitude to the Beas and Sutlej, where it falls again to 4,000 feet, which is its altitude about Nahun and the Jumna. In the Deyra Dhun it is only 3,000 feet, but east of the Ganges, where there is a local bend in the strike, it rises again considerably. Beyond this the country has not been visited by me. In the eastern area, under Darjiling, it is of little elevation, but rises to about 4,000 feet, disappearing altogether near Dalingkote, but near Buxa the formation reappears, and is only some 2,000 feet. Nothing is known of the older tertiary rocks up to the Aka and Dafla Hills, but here they attain again large proportions—4,700 feet west of the Ranga to 6,000 feet beyond that river. South of the Assam range, miocene strata, a distinct group, attain 1,500 feet, but are poorly represented in places. At other points, as near the Sylhet *bhils*, they are absent. Near Jaintiapur they expand and reach an altitude of 3,000 feet. South of the Lukah River the whole mass gradually rises to 5,000 feet near Asalu, and to 9,890 at Japvo Peak, its culminating point in the Naga Hills; but these formations are, I believe, marine and estuarine. The great elevation of tertiary rocks here is the exact counterpart of what has taken place on the west, and both are on the great changes of strike in all the formations.

Within the mountains in the old rock basins—and these are analogous to the valleys of the Alps—are pliocene and post-pliocene beds of great thickness, but of fresh-water origin; the remnants of which are to be seen in Kashmir and Scardo at intervals, along the valley of the Indus, and that large—now elevated—accumulation at the head of the Sutlej River in Hundes, first brought to notice by the labours of Captain (now General) R. Strachey. The remnants of these deposits in Kashmir and Scardo are found preserved in the more sheltered portions of the valley basins, untouched by the denuding action during the glacial period—the exponents presented to us of the enormous denudation that went on during the post-pliocene times, of which the glacial period formed a part. The extent and displacement of the upper pliocene beds is in North Italy and here very similar. Often abutting horizontally against the mountains, they are in other places found tilted at considerable angles on the margin of their original extension. When we examine their contents, we find that the fauna of that time in Asia, as well as Europe, was more African in character, and genera now confined to that continent were abundant far to the north. The sluggish rivers and lakes of Sivalik times in Asia and of the corresponding period in Europe were the home

of the hippopotamus, crocodiles, and tortoises, of which the common crocodile, the gavial, or long-snouted species, and an emys have survived the many geological changes, and still inhabit the rivers and low grounds of India to-day. The fresh-water shells are still the same now as then. Many species of antelope lived in the neighbouring plains and uplands; the elephant was there in the zenith of its existence, for no less than thirteen species have been found fossil in Northern India; but it is impossible, in a short address, to enumerate the richness of this fauna, and the extreme interest that surrounds it.

Miocene of European Area.—If we now turn to Europe to compare formations of similar age, Lombardy and the valley of the Po, with the southern side of the Alps, present to us somewhat similar physical features. A large area of about the size of the north-west Panjab, once a part of the miocene sea, is occupied by a remnant of rocks of that age, considerably elevated and tilted, but not to such an extent as those of the Himalayas. Near Turin these dip towards the mountains, and a very short examination shows the undoubted glacial character of some of the beds; [1] and, as the whole formation is marine, their large sharply angular material, much of which is jurassic limestone, was probably transported from the adjacent mountains by the agency of ice in a shallow sea.[2] After the great crushing and alteration of the previous outlines of the whole country another sea filled the basin of the Po, and pliocene deposits were laid down in a sinking area extending to the base of the mountains all round the new bay or gulf. Re-elevation again set in, and with it, or soon after it, the advent of another, and the last, glacial period. But the bounds of the pliocene sea extended even farther than the base of the mountains. At the south end of the Lago d'Orta, well within the hills, sheltering under the isolated porphyry hill of Buccione, and 280 feet above the present lake (or 1,500 feet above the sea), I had the good fortune to discover this summer a patch of pliocene sands and clays, with marine shells in excellent preservation, which I am not aware has been noticed before. Sixty-four feet of the section is exposed, capped by moraine matter; its base was not seen, and the beds dip north. This remnant tells us a good deal. From where it rests there is a clear horizon to the north down the lake to the junction of its river with the Toce—unmistakable evidence that these beds must have extended far in this northern direction, and that long fiord-like arms of the sea stretched up as far as Domo d'Ossola on one side, and Bellinzona on the other. This marine bed is far above the level of the Lago Maggiore, but I may mention that I also found marine shells of pleistocene age 112 feet above that lake near Arona, of which details cannot here be given.

Before the last great elevation of the Alpine chain the old line of sea-coast, therefore, ran even high up the long deep valleys of Maggiore, Como, Garda, &c., during the early pliocene period; the mountains then, quite as high as now, enjoying a warm, moist climate, not a glacial one. Then came the gradual but uneven elevation of the whole area, including the miocene hills south of the Po, and lacustrine and estuary conditions prevailed over much of the plain country. The lapse of time was probably enormous, and as the land rose and the sea retired the climate gradually became cooler, and ushered in the glacial period. I do not think it would be an exaggeration to add another 5,000 feet to the Alpine peaks of that time, which would give them an altitude equal to the Zaskar range of the N.W. Himalayas of the present day. With the change and the increased volume of the mountain torrents, the destruction of the upraised marine pliocene beds commenced, and finally culminated in the extreme extension of the glaciers, even into the plains; they scoured out almost completely the whole of these deposits, which then filled the great valleys and the country at the base of the mountains, to redistribute them again over the plain of the Po, and silt up what remained there of the old estuary

[1] Martius and Gastaldi. *Bull. Soc. Géol. France*, ser. 2, tome vii. pp. 554–603 (1850).

[2] No trace has been observed of this glacial period in the miocene of India; the most lofty portions of the chain had not then attained a greater elevation probably than 14,000 to 18,000 feet, and the outer axis lines far less. However, in the tertiary beds (middle Eocene?) of the Indus Valley below Leh, such conditions are indicated by Lydekker. *Memoirs of Geological Survey of India*, vol. xxii. p. 104, which I have received since this address was sent to press.

or gulf towards the east. The denudation of this formation has been enormous along the base of the Alps, and only mere remnants are to be found. It is easily seen that their preservation is purely due to the accidental position in places where the great denuding force—viz., the advance of ice from the mountains—has been unable to touch them; in other instances the early deposition of moraine matter upon them has acted like a shield, and prevented their entire destruction. Such examples are well seen near Ivrea, in the well-known section in the gorge of the Chieusella near Stombinella, and in the moraine near San Giovanni.

The scattered remnants of the pliocene formation south of the Alps, which took perhaps thousands of years to lay down, show well how soon a great formation, together with the preserved remains of the fauna living at the time, may be completely destroyed by subsequent denuding forces. Similar destruction must have occurred over and over again in past geological ages, and shows clearly how the scanty, broken record can be accounted for.

It is an established fact that the great valleys of the Alps and Himalayas existed much in their present form during miocene times, and they may owe their excavation partly to the glacial action of that period, when these mountain slopes rose from the plain or margin of the ancient sea, far in front of the present line of slope, and were far higher than now. This idea particularly strikes one when looking at the ice ground spurs that run out into the plain south of the Lago d'Orta. The general and local elevation and depression that took place in post-miocene times seem quite sufficient to account for the difference in the comparative levels of adjacent transverse valleys, or an elevation along the base of the chain, clearly indicated at Orta by the northerly dip of the marine beds. It is reasonable to suppose that these movements were exerted in different degrees, at points all along this face of the Alps and within the same, and that the depression on the west has been less than on the east, so that the sea never extended far up the valley of Susa, and to a comparatively short distance up that of the Dora Baltea as compared with Maggiore, and the formation and excessive depth of this and similar lakes on the east is mainly due to this local depression and elevation. Depression has steadily continued in the delta of the Po, as in the Ganges at Calcutta; for, at Venice, borings showed depression of land surface to an extent of 400 feet, and they did not reach the base of the formation.[1]

It is not improbable that during the earlier extension of the glaciers into the Maggiore basin,[2] the sea still had access to it;[3] this would have greatly aided in the removal of the marine deposits, and then the deeper erosion of its bed near the Borromean Islands, so well put forward by Sir Andrew Ramsay. When we see the gigantic scouring which glaciers have effected in the hardest rocks on the sides and bottoms of valleys, when we know for certain the enormous thickness they reached in the Alps, I do not doubt for a moment their capability of deepening a rock basin very considerably, or their power to move forward over and against slopes so low as 2° to 3°.[4]

The earliest extreme extension of the glaciers was very great; we have evidence of it on the miocene hills near Turin, their surface being scattered over with transported material of great size, quite unconnected with that other ancient period of glacial conditions during the miocene times mentioned above at a period too remote to further dwell upon here. Even now I feel that in dealing with this subject of the glaciation of the Alps, many of you may say that I am departing too much from geography. To this I would answer, glacial periods have been so intimately connected with the interchange of sea and land conditions, that where can

[1] Lyell, *Prin.* vol. i. p. 426.

[2] With reference to the moraines of Ivrea, see pamphlet by Luigi Bruno, *I terreni costituenti l'anfiteatro allo sbocco della Dora Baltea.*

[3] The evidence is stronger as regards the *Lago Garda.*

[4] There appears to be too great an advocacy, on the one hand, of ice action having done all the work of denudation; while, on the other, some writers consider this to have been extremely limited; it is the combination of the two forces, I think, that effects so much and in so different a manner and degree.

the line be drawn in physical geography between the past and the present? It is as undefined as the line which separates species from genera.

An enormous interval of time must have elapsed, during which the cold was increasing and the glaciers advancing, and during which the rivers were distributing the consequent waste over the lower country, spreading out the more or less coarse material, sands and clays, in broad fans in front of all the great gorges. Then came the first period of contraction of the glaciers, with many oscillations. Of this we have the evidence in the moraines of Ivrea, Maggiore, &c. Sections of these moraines show how they were piled the one upon the other; how the building up of one line of lateral moraine was followed by its partial destruction on another forward movement of the ice, and the throwing down of another moraine upon it. Then were formed many of the smaller lakes, remains of which lie amid the débris thrown out into the plain. The glaciers retained this size for a very considerable time, and then apparently very rapidly retreated to far within the mountains, but still for another considerable period their dimensions were much larger than those of the present time, into which they seem to have again rather rapidly shrunk.

Passing from the glacial action displayed in the outer Alps to that in the Himalayas, we find ample evidence of a period of great extension of such conditions, first in the erratics of the Attock plain and the Potwar,[1] lying fifty to sixty miles from the gorge of the Indus at Torbela. We have again the fact that in Baltistan, in the Indus valley, glaciers have twice descended far beyond their present limits, first down to Scardo itself, and then to some thirty miles below their present limits; while the glaciers of Nanga Purbet, towering above the Indus some 22,000 feet, must have descended into the bed of that river. Even allowing that the Potwar was not formerly a lacustrine basin, the great *débacles* from the mountains would have been sufficient to convey erratics fixed in ice to where they now lie. Cataclysms of the present time, caused by glacial obstructions, have raised the level of the Indus on the plain above Attock so much as eighty feet. When these glaciers were more than double their present size, gigantic floods must have often taken place, and formed boulder deposits high above present levels: such high level gravels are to be seen not only in the Potwar, but also in the Naoshera Dhun on the Rajaurie Tawi River, containing boulders of nummulitic limestone and other rocks of the Pir Punjal on the north.

Again, north of the Chatadhar ridge, small glaciers, five to six miles in length, at one time filled the lateral valleys, descending towards the Chenab River to about 5,000 feet; and a very perfect moraine occurs in one valley. This ground must be very similar to that which has been described by Theobald as occurring in the adjacent Kangra district[2] on the flanks of the Dhaoladhar ridge. Similar small glaciers existed, I believe, in the valleys of the Kajnag range, but I think that neither in this range nor in Budrawa did they ever descend into the main valleys; but the existence of these glaciers, together with the large snow-beds, had much to do with the formation of the high-level gravel-beds and fans through which the Jhelum and Chenab have since cut their way.

In fact, examples of the former extension of glaciers are wide-spread along the chain of the Himalayas from west to east. True moraines, and moraine-mounds, at 16,000 feet on the north side of the Baralasa pass, attest the presence of glaciers on the elevated plain of Rukshu, where now the snow-line is over 20,000 feet.[3] Drew gives much valuable information regarding their former size.[4] On the east, in Sikkim, Sir Joseph Hooker[5] has described moraines of great height (700 feet) and extent.[6] Still further south and east, in the Naga Hills, a short period of greater

[1] A. Verchère, *J. Asiat. S. Bengal*, 1867, pp. 113–114; Theobald, *Records of the Geological Society of India*, 1877, p. 140. [2] Ibid. 1874, p. 86.

[3] North of the Karakoram, in that now arid country, great moraines are found in the valleys that descend into the Karakash, in the neighbourhood of the Sujet pass, 17,600 feet. (*Letter and Sketch*, by Mr. Harold Godwin-Austen.)

[4] *The Jummoo and Kashmir Territories.* [5] *Himalayan Journals*, vol. i. p. 221.

[6] The equivalents, although very small, of such moraines are to be seen in the Alps on the Simplon jutting out into the valley.

cold is indicated by the moraine detritus under the loftiest portion of the Burrail range in latitude 25° 30′.[1]

Whatever may have been the length of the glacial period in the Alps—and it was very considerable—in the Himalayas it cannot have been so long and so general, although, to a certain extent, contemporaneous.

In the Alps glaciation meets the eye on every side, and the mountains, up to a distinct level, owe their form and outline to its great and universal extension.

In the Himalayas it is difficult to trace polished surfaces or striæ markings, even in the neighbourhood of the largest glaciers that are now advancing in full activity. It has been suggested that obliteration is the result of more powerful denudating forces, but the conditions are not so very dissimilar in the high Alps and high Himalayas as to warrant this; and wherever the oldest striæ marks occur in the Himalayas, they are situated near the bed of the valley. It may interest you if I give an illustration or two of the size of these present glaciers as compared with those of the Alps. The Baltoro glacier would extend, if placed in the Toce valley, from the Simplon to the margin of the Lago Maggiore; or, take another illustration of its length, from Mont Blanc to Châtillon in the Valle d'Aosta.

Although of such great length, these Himalayan glaciers could never have reached the enormous thickness which the earlier Alpine glaciers attained. This may be thus accounted for: in the European area a generally low temperature prevailed down to the sea-level, while in the Himalayan it was local, and confined to a higher level. It is evident that the snow-line has altered—higher at one period, lower at another—down to recent times, denoting changes of the mean annual temperature, which are not yet fully understood, but have been attributed to very far distant distribution or alterations of land, sea, and the ocean currents.

Two periods of glacial extension are clearly defined, separated by a milder interval of climate: during the earlier glacial period the Indus valley was filled with those extensive lacustrine and fluviatile deposits, mixed with large angular débris, such as we see at Scardo, which may be coeval with the extreme extension of the Alpine erratics so far as the miocene hills south of Turin.

The second period followed after a long interval of denudation of the same beds, and would correspond with the last extension of the great moraines of Ivrea, Maggiore, Como, &c., followed by a final retreat to nearly present smaller dimensions. Nowhere on the south face of the Himalaya do we find valleys presenting any features similar to those of the Southern Alps, particularly on the Italian lakes, which are, I believe, the result in the first place of marine denudation, succeeded by that of depression and finally powerful ice-action. On the south face of the Khasi and Jaintia Hills, however, which are orographically connected with the peninsula of India—the conditions altogether different—we find long stretches of water of considerable breadth and depth extending within the hills, and not unlike in miniature the Italian lakes. These valleys, worn out of the sandstone and limestone rock, have been formed here, I think, to some extent by the aid of marine action, and the subsequent depression along this line of hills, also marked here, as in the Western Bhutan Doars, by the absence of beds newer than the nummulitic.

This attempt to bring before you some of the great changes in the geography of Europe and Asia must now be brought to an end. It is a subject of vast time, of absorbing interest. I am only sorry it is not in more able hands than mine to treat it in the manner it deserves, and in better and more eloquent language; but it is a talent given to but few men (sometimes to a Lyell or a Darwin) to explain clearly and in an interesting form the great and gradual changes the surface of the earth has passed through. The study of those changes must create in our minds humble admiration of the great Creator's sublime work, and it is in such a spirit that I now submit for your consideration the subject of this address.

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[1] Godwin-Austen, *J.A.S.B.* 1875, p. 209.

The following Papers and Report were read:—

1. *On the Hot Springs of Iceland and New Zealand, with Notes on Maori Customs.* *By* CUTHBERT E. PEEK, *F.R.G.S.*

The author commenced by giving a description of the hot springs of Iceland and New Zealand, both of which have been recently visited by him. Several most important differences were noticed in their composition; in the case of the hot mud wells of Iceland, there is so much copper suspended in the mud that several Companies have been started to work them commercially; while the mud springs of New Zealand are so full of *Infusoria* that in times of famine the natives manage to sustain life on a diet chiefly consisting of mud. Some of the New Zealand springs contain a very large percentage of mineral, and the analysis of one of the most powerful was—

Chloride of sodium .	93·46	grains.
„ potassium .	4·69	„
„ lithium traces.		
Sulphate of soda . .	2·76	„
Silicate of soda . .	6·41	„
„ lime . .	2·89	„
„ magnesia .	1·02	„
Iron and alumina oxides	2·10	„
Silica	8·29	„
Total, per gallon .	121·62	„

The hot springs of New Zealand appear to extend from Mount Tongariro, at the S.W. end of the system, to White Island at the N.E. extremity. On April 25, Tongariro was observed to be giving out more smoke than since 1870, when a considerable eruption took place. The two most remarkable objects in connection with the New Zealand geysers are the Pink and White terraces, situated on Lake Rotomahana; these consist of regular steps, each of which forms a small basin full of the clearest water; in the case of the White terrace the water has a beautiful sky-blue appearance, while at the Pink terrace the whole is tinged with a delicate salmon colour. The upper basin in each case is about 80 feet above the level of Lake Rotomahana. The whole of the country round is covered with hot springs and mud wells, and the greatest caution is required to avoid an accident, which would probably be fatal. Several curious Maori customs were mentioned, the most remarkable being *mana* and *tapu*; now, however, owing to contact with Europeans, most of the native customs have become obsolete.

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2. *Notes on the Territory of Arizona.*
By LITTON FORBES, *M.D., L.R.C.P., F.R.G.S.*

The author, after alluding to the general ignorance as to the rich territory of Arizona, pointed out that it was now practically opened up, for the first time in its history, by the completion, in the last days of May 1883, of the new Atlantic and Pacific Railway, which will probably revolutionise before long the existing lines of travel, not only to Australia, but also to China and Japan. This new line, which may be considered an extension westward of the great trunk line of the Atchison, Topeka and Santa Fé, runs from the old Spanish-American city of Albuquerque in New Mexico, passes through the northern portions of Arizona, and joins the Southern Pacific at Mojave in California. It thus forms a complete trans-continental line, on a parallel considerably to the south of any previously existing line. Its indirect connection, however, with the Southern Pacific, and the new Sonora line in Mexico is extremely important. The Sonora line has its terminus at the port of Guaymas, on the Gulf of California. Here probably, in the not far distant future, will be the new port of arrival, at least for mails and passengers bound eastwards from Australia, China, and Japan. At present, Guaymas is a small

Mexican town consisting of adobe houses. Its harbour, however, is an excellent one, with deep water up to the very shore, and well sheltered from every wind. It is the only possible mail station on the Gulf of California, and is some five hundred miles, or nearly two days' steaming, nearer Australia than is San Francisco. The new Atlantic and Pacific line in its course through Northern Arizona also opens up a very important tract of country. Of all the Western Territories, Arizona has long been the most remote and inaccessible, and therefore the least known. It has been neglected in turn by the miner, the stock-raiser, and the farmer. The aridity of the climate, and the presence of hostile Apache Indians, has had much to do with this, but it has been due in a still greater degree to the want of suitable means of communication. As the Territory is now provided with two distinct systems of railway, it is believed that the long isolation from which, since the days of the Spanish conquerors, the country has suffered, will be soon broken through. Arizona is a country of extraordinary mineral wealth. In many parts of its extensive territory, it offers large tracts of excellent land to the farmer and the stock-raiser. Its chief drawback is a want of water, but this can be supplied as required by irrigation works and by Artesian wells. Coal, salt, and the precious metals exist in Arizona in larger quantities probably than in any of the Western mining territories. The copper mines are even now the richest known, but as the country is opened up still greater returns will probably be obtained. The area of the territory is about 114,000 square miles, or approximately 73,000,000 acres; in other words, three times the size of the State of New York. The general topography of the country is that of a plateau sloping towards the south and west from an altitude of 7,000 feet to the sea-level. The surface of Arizona is much diversified, and contains some of the finest scenery in North America. In no country of the world can the evidences of past geological action be better studied. The Cañon of the Colorado is a stupendous water-worn chasm, 400 miles long, and from a quarter of a mile to a mile and a quarter in depth. The scenery in many parts of Arizona is grand and impressive; in others, the landscape is little better than a desert. The whole country is still a strange mixture of the old and new. Life there is in its main features much the same as it was when Coronado, in 1540, led his bands of Castilians through the country in search of the 'Seven Cities.' But this phase of existence is rapidly passing away, and before long Arizona will awake from the sleep of centuries which has till now weighed upon her.

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3. *Preliminary Report on Local Scientific Societies.*—See Reports, p. 318.

FRIDAY, SEPTEMBER 21.

The following Papers were read:—

1. *On the proposed Jordan Channel. By* Trelawny Saunders, *F.R.G.S.*

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2. *On the Jordan Valley. By the* Rev. Canon Tristram, *D.D., F.R.S.*

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3. *On Kairwan. By* Edward Rae, *F.R.G.S.*

The author, who visited the holy city in 1877, gave a sketch of its past and present topography, with a more detailed account of its history. Till the last few years no city of Kairwan's importance and antecedents was so little known; for Christians could only visit it at great risk. In 1835 the Marquis of Waterford was stoned; and Mr. Rae was cursed and threatened, and his servant had to escape for his life.

Kairwan—founded, according to Mohammedan tradition, by divine inspiration—rapidly grew in extent and power. Its mosque with five hundred columns, its

vast population, its gorgeous summer-palaces, its caravan trade, its wealth and learning, its marvellous conquests, but, above all, its inviolate and holy character as a city of pilgrimage, made it one of the wonders of the Mohammedan world.

Conquerors of Spain, Barbary, and Numidia, of Corsica, Sardinia, and Crete, the warriors of Kairwan carried fire and sword into the suburbs of Rome itself. Its influence upon science, commerce, and the arts—in fact, upon civilisation generally—has left imperishable traces.

The recent capture of Kairwan by the French, and the desecration of its shrines, was to the natives a shock almost too great to be realised by anyone who had not visited the city before its fall.

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4. *A Journey in Russian Central Asia, including Kulja, Bokhara, and Khiva. By the* Rev. HENRY LANSDELL, *D.D., F.R.G.S.*

The author described a six months' journey performed by him during the latter half of 1882, of 12,145 miles (5,000 by rail, 3,400 by water, 3,000 by road, and 800 in saddle, or cradle), having for its principal object the distribution of religious literature in prisons and hospitals, and the collection of ethnological and general information.

Leaving London, June 26, the author arrived at Tobolsk on August 12, and steamed up the Irtish to Omsk, the capital of the new general government of the Steppe, lately formed of the provinces of Akmolinsk and Semipalatinsk out of Western Siberia and the province of Semiretchia, hitherto part of Russian Turkistan. This general government, with that of Turkistan (consisting of the provinces of Syr Daria, Amu Daria, Fergana, and Zerafshan), now makes up 'Russian Central Asia.' In fourteen days from August 19, the author posted 1,198 miles through Semipalatinsk, over the Chingiz-tau, passing the east end of Lake Balkash, and up the Ili valley to Kulja. Here he visited a Sibo encampment, and the Chinese governor at Suidun, after which he followed the post road through the towns of Vernoi, Auli-Ata, and Chimkend, to Tashkend. Dr. Lansdell then proceeded southwards to Kokand and Samarcand, and crossed the Hissar mountains at the Takhta-Karacha pass (5,180 feet) to Shehr-i-Sebz, where he was received by the Emir of Bokhara, and treated as a guest during his stay in the Khanate. Proceeding thence 148 miles, through Chirakchi and Karshi, he arrived on the sixth day at the City of Bokhara. Leaving this place on August 16, he passed through Kara-kul, and across the Sundukli sands to Charjui, a journey of 48 miles in three days, and then, with 6 horses, a tarantass, 2 interpreters, 8 oarsmen, and 5 mounted guards on shore as a protection from the Turkomans, he floated down the Amu-daria 300 miles, to the Russian fort Petro-Alexandrovsk, reaching it safely on October 26. Dr. Lansdell then re-crossed the Oxus to Khiva, and twice had audience of the Khan, after which he left on November 2 for a journey of 107 miles on horseback through the cultivated districts of Shahkhavat, Tashaus, and Ilyali, to Kunya Urgentch, where a most interesting visit was paid to ruins said to date from the time of Genghis Khan. The author next prepared, with 2 interpreters, 2 camel-drivers, 2 horses, and five camels, to cross the Aralo-Caspian desert. Proceeding by the well of Karategin, the last shepherd was spoken with on November 10, after which the party met no human beings for eleven days. The route lay along the old Oxus bed to the Sarykamish lake, and then continued in a south-westerly direction to wells at Uzun-kuyu, and Kazakhli, after which the travellers descended into the dry bed of an inland sea, and skirted the cliffs of Kaplan Kir. The wells of Sekhiskhan and Tuer were passed, after which, from the summit of the Sari-baba hills, was seen the Kara-Boghaz bay of the Caspian. The well of Demerdjen was safely reached, Suili was passed, and on November 22, after a journey of 403 miles from Kunya Urgentch, the party arrived at Krasnovodsk. Dr. Lansdell then crossed the Caspian to Baku, whence, after visiting the oil wells and naphtha fires of the neighbourhood, he proceeded by the new, but then unopened, railway to Tiflis, and so home by Poti and Odessa, having fully accomplished the objects of his journey.

SATURDAY, SEPTEMBER 22.

The Section did not meet.

MONDAY, SEPTEMBER 24.

The following Papers and Report were read:—

1. *A Visit to Mr. Stanley's Stations on the Congo.* By H. H. JOHNSTON.

Towards the end of December 1882 the author visited Mr. H. M. Stanley at Vivi Station, which he describes as about 360 feet above sea-level, and rising 270 feet clear above the Congo. The projecting mass of cliff on which it is placed becomes higher as it nears the river, and is almost unapproachable except from the inland side. On the summit and the riverward edge of the cliff is a flat and level platform, nearly artificial and about 80 feet square, on which the most important houses are built.

On January 7 he left Vivi for Isangila and Stanley Pool, accompanied by three picked Zanzibaris as personal servants. The journey to Isangila, the next station to Vivi, occupied three days and a half. The road was nothing more than a native path, in many places lost in marsh or invisible and untraceable in the high grass. The scenery between Vivi and Isangila is very beautiful in parts, an alternation of green hills and thickly forested ravines, with many tumultuous streams. Isangila Station, like most of Stanley's establishments, is placed on a high hill above the river. The great rapids or falls of the Congo opposite the station are very grand. Between Isangila and Manyanga is a distance of eighty miles, which it took four days to accomplish in a little river-steamer. The current is terribly strong, and the scenery here poor and uninteresting. Manyanga is a fine station and very well provided with native food. Five hundred eggs may sometimes be bought in one day at the neighbouring market. From Manyanga to Lutété, on the south bank of the Congo, is about twenty miles. Lutété is a bright and pretty little station near a very large native village, from which it takes its name. From Lutété to Stanley Pool, about eighty miles, the scenery is beautiful and the country well populated. All along this great ivory route, the pine-apple, introduced by the native traders from the coast, grows abundantly. Ngoma is the next of Stanley's stations, and fifteen miles beyond is Leopoldville, situated at the opening to Stanley Pool. It is placed on a commanding height looking down on the opposite shore, where Mfwa, or 'Brazzaville,' is prospectively situated. Here there were only six or seven native huts, and the inhabitants retained little, if any, remembrance of the hasty passage of De Brazza. The scenery on Stanley Pool, with its many wooded islands, high cliffs, and distant mountains, is described as enchanting. At the further entrance to the pool is Kimpoko, a pretty little station embowered in Borassus palms. The journey up stream to Msuata, near the mouth of the great Ibhbuma-Quango river, occupied six days in a rowing boat. At Msuata Station Mr. Johnston passed six weeks, the scenery and natural history of the district being most interesting. From Msuata to Bólóbó, another week's journey, the scenery became increasingly beautiful—Bólóbó itself, with the splendid broadening of the Congo and the matchless forest scenery on its banks, being difficult to describe adequately. Life is rendered miserable at this station by the incessant plague of mosquitoes. The author's explorations terminated with a day's journey beyond this station.

The principal races on the Congo between Bólóbó and Stanley Pool are the Batéké, the Bayansi, and the Wabuma. All these peoples are comparatively recent settlers on the river. The Batéké are what might be called resident colonists from the north-west between the Ogowé and Congo. The Bayansi have come down the river from the Equator and the north-east, and are the great travellers and traders of the Upper Congo. The Wabuma are the people inhabiting

the river Quango in its lower course. They would seem at some former time to have been driven from the north-west before the Batéké, and to have crossed the Congo. They are often made slaves of by the Batéké and Bayansi, and are a less handsome race than these latter. They appear to be allied in language and origin to the Aboma, encountered by De Brazza near the Upper Ogowé and the Alima River.

All these natives on the Congo are kindly, merry, and courteous in behaviour, with splendid physical development, and great artistic skill shown in decorating their utensils and weapons. Their languages are dialects of the most thorough 'Bantu' character. That of the Wabuma is strongly guttural—otherwise in many of its words it offers some resemblance to the Mpongwé of the Gaboon. The Batéké is more allied to Congo, and the Bayansi presents some resemblance to the East Coast tongues. In all these languages there are many words almost identical with the Kaffir, Kiswahili, and Damara tongues. Zanzibaris can often make themselves understood in their native dialect on the Congo.

The natural history of the Congo may be divided into three regions—the district of the coast, the cataracts, and the Upper Congo beyond Stanley Pool. The coast region is simply swampy forest country, exactly similar to the Gold Coast and Upper Guinea in its flora and fauna; the cataract region is poor, and more resembles Angola in its natural history. At Stanley Pool a great change takes place in the fauna and flora, and many new forms of birds, insects, and plants suddenly appear. This same character of fauna and flora apparently continues, according to Stanley, unaltered to the Stanley Falls. It may also be noticed that Schweinbürth observed on the Upper Wellé some forms of plants, more especially palms, which Mr. Johnston first saw at and beyond Stanley Pool.

The climate of the Upper Congo is very agreeable, and in the author's case healthy. The greatest heat registered at mid-day was 96° in the shade, but the normal and almost unvarying temperature at noon was 87° and at night 65°.

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2. *Report of the Committee appointed for the purpose of promoting the Survey of Eastern Palestine.*—See Reports, p. 308.

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3. *On the Volcanic and Earthquake Regions of Central America, with Observations on Recent Phenomena. By* WILLIAM HANCOCK.

The author entered Mexico at Acapulco on November 12 last year. Crossing the Rio de la Venta he arrived at La Providencia on a table-land at 2,000 feet, and at the base of the Sierra Madre, then examined the extinct volcano of Zapotilla (3,000 feet). From Mexico he travelled by sea to San José de Guatimala, and thence to the lake of Amatitlan. The volcano of Pacaya (8,400 feet) was ascended from this point. A regular truncated cone rises from the interior of an ancient crater. The summit contains a crater, about 250 feet in diameter by 100 feet deep: the circumference is fissured, and moderate volumes of steam were issuing from the fissures. Chemical action was not apparent. The last great eruption was in 1775. A parasitic cone exists against one side of the ancient crater rim in the interior.

Between Amatitlan and Guatimala enormous deposits of pumice were passed. The Guatimala plateau approaches the lake in an escarpment exhibiting a trachytic formation. The region round the volcanoes Aqua, Fuego, and Acatenango was visited. The last eruption of Fuego was in July 1880; lava was discharged on the Pacific slope. During the author's residence in the district, *retumbos*, or underground rumblings, were not infrequent. From Guatimala Salvador was reached, and the volcano of Izalco ascended as far as possible. The eruptions occurred on an average once in thirteen minutes; the smoke and vapour rose to from 1,000 to 2,000 feet above the crater; showers of pumice and sand were ejected. Several slight earthquake shocks were experienced at San Salvador. The lake of Ilopango was visited, and the volcano in the centre, which came up on January 20, 1880, and is gradually sinking again. Between December 24 and 30, 1879, 372 earthquake shocks were recorded at the lake side. The water had a strong odour of sulphuretted hydrogen.

From Salvador the author proceeded to La Union in the Gulf of Fonseca. The islands are all extinct volcanoes. Cosiguina was passed. During the eruption of January 20, 1835, the ashes were carried to Jamaica and Santa Fé de Bogota, and the explosions were heard at Belize, 800 miles distant. Journeying from Corinto to Managua in Nicaragua, the volcanoes of El Viejo, Santa Clara, Telica Orota, Acosusco, Las Pilas, and Momotombo were passed. Momotombo rises from the edge of the lake. Near Managua the sunken craters were filled with water; Tiscapa, Nihapa, and Asosoca were examined, and the volcano of Masaya was ascended. The twin volcano of Nindiri exhibits an ancient crater, shallow, and having a flat circular floor. Subsequently it burst again into eruption from two new craters, one at each side and within the original crater, and the undermining by the expulsion of lava caused the original floor to drop in three steps, leaving terraces all round.

The author considers that the existing volcanoes of Masaya and Nindiri are merely cones in the centre of a flat crater about 20 miles in circumference. The lake of Masaya is included within the walls. It is approached by a path down the face of a crater-like precipice, 350 feet in height; the lake is 400 feet deep. The volcano of Mombacho was seen at Granada, and several of the volcanic islands in the lake of Nicaragua were visited, including Zapatera, which exhibits a sunk crater filled with water. The adjacent island of Ometepec the author was prevented from visiting through unfavourable weather; since then (February), according to accounts received, the volcano of the same name has broken out in eruption after years of repose, and the inhabitants have retired from the island.

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4. *Nos Vey and the South-West of Madagascar.* *By the* Rev. S. J. Perry, *F.R.S.*

The Government expedition for the observation of the Transit of Venus on December 6, 1882, was the occasion of a visit to the South-West of Madagascar. The observers were the Rev. S. J. Perry and the Rev. W. Sidgreaves, accompanied by Mr. W. Carlisle. They were landed by Captain Aldrich, R.N., from H.M.S. *Fawn*, on the small island of Nos Vey, a few miles south of St. Augustine's Bay, and this paper contained the results of their observations of the country and its inhabitants during their short stay of a few weeks.

After a brief sketch of the history of the establishment of the French and English traders at Nos Vey, a description was given of the native tribes, of their character and general treatment of Europeans, of their dress, dwellings, religion, charms, and customs. The peculiar state of slavery among the savages of the South-West of Madagascar was dwelt upon at some length, and also the nature of the authority exercised by the petty kings. The paper concluded with some remarks on the natural history and climate of Nos Vey.

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5. *On the Somali and Galla Countries.* *By* E. G. Ravenstein, *F.R.G.S.*

The author, having given a sketch of the history of geographical explorations in these countries, dwelt upon the native information available for the compilation of the Royal Geographical Society's map of Equatorial Africa, and finally enlarged upon the information obtained by the Rev. C. Wakefield from natives. He pointed to Kisimayu as a port presenting peculiar facilities to a traveller desirous of penetrating into the country of the Bworani Galla.

TUESDAY, SEPTEMBER 25.

The following Papers were read:—

1. *On New Guinea: a Sketch of the Physical Geography, Natural Resources, and Character of the Inhabitants.*[1] *By* Coutts Trotter, *F.R.G.S.*

The author attributes the ignorance and indifference hitherto prevailing on the

[1] See the *Science Monthly* for Dec. 1883 and Jan. 1884.

subject to causes which have ceased to operate, as, first, the difficulties of the navigation, now minimised by steam; secondly, the exclusive system of the Dutch in the Spice Islands, which hindered explorations of the regions further east, and latterly the diversion of the stream of enterprise towards Australia. As regards the first, the unsurveyed reefs and channels of Torres Straits, the mud flats and shallows further west, the concentrated violence of the monsoon on the south coast, and the precipitous and harbourless character of the northern, were no doubt formidable to sailing vessels; but it is strange that the position, central between India, China, and Australia, never attracted official exploration.

New Guinea was actually discovered about 1526–28. More is probably due to the old Spanish navigators than is usually supposed. By the time of Torres, who achieved the Southern passage in 1606 (though this is given, mysteriously, in maps of earlier date), the whole coast line, excepting the north coast from Cape Finisterre eastwards, was roughly known. The author traces its geological relations with Australia, showing the date of their separation to be probably not earlier than the Lower Miocene, shells of that period being found on the east of the Gulf of Papua identical with those of the same series in Victoria and South Australia. Of the New Guinea amphibia, too, those not of wide distribution are exclusively Australian. On the west side of the Gulf, from the swampy plains intersected by the Fly and other streams which bring down the drainage from the mountainous interior, isolated hills of Australian character rise abruptly, which apparently, like the higher islands of Torres Straits, escaped the submersion which insulated both. The plains, since they emerged, have been mainly occupied by an Indo-Malay vegetation. The palæozoic rocks of the Eastern Peninsula, judging from small specimens of mica slate, quartz, sandstones, greenstones, and jasperoids, are undistinguishable from the Silurian and Devonian series of the New South Wales goldfields; but as yet gold has been found only in very small quantities. The mountains in the north-west seem chiefly granite and gneiss. From the Gulf of Papua to Princess Marianne Island the sea is so shallow and the coast so low that land is invisible from shipboard. Here a great submarine bank extends to the Aru Islands, which Mr. Wallace shows to have formed part of the mainland of New Guinea. The west and north coasts are chiefly precipitous (the cliffs frequently of recent limestone with raised coral beaches), broken by considerable rivers affording access to the interior. Otherwise the densely wooded mountain ranges make such access difficult, though in places these rise in terraces which are highly cultivated. The north coasts are almost free from reefs, which, however, skirt the south coast of the Eastern Peninsula, forming within them valuable harbours and anchorages. Vessels stationed in these would command the passage both of Torres Straits, and of China Straits at the eastern extremity, which are the important routes from Australia to India and China respectively. The interior here consists of ranges of rolling grassy hills, sparsely wooded with acacias, eucalyptus, &c., and interspersed by streams and fertile tracts well fitted for tropical cultivation, as sugar, &c. Beyond is the central range, 13,000 feet.

Severe earthquakes occur on the north coast, but no active volcanoes have been seen. They may however exist, and Mr. W. Powell observed a mass of pumice at a considerable height, opposite to New Britain, but the great volcanic energy of that island seems to die away in the small islands to the west, and to pass north-west, through the Schouten group, towards the Moluccas and Philippines.

The forests contain magnificent timber, fruits, spices, barks, and gums. The sago palm (about which statistics are given) and sugar may become great staples. There are also tracts suited for cattle-raising. It is a question how far the good lands are unoccupied. The natives have a keen sense of rights in the soil, individual and tribal, and even in the fruits of the forest trees and the fish of the streams belonging to the tribe; and they probably would not work regularly for Europeans. Perhaps confidence might be created first by establishing trading depôts. There is an active trade between the hill and coast tribes in their respective produce and manufactures, and in Western New Guinea a small foreign trade—sago, massoi bark, and bird-skins being the chief exports, but their wants are very few; thus,

though the resources of the country are great, the chances of immediate profit from their development are doubtful.

The people of the northern coasts generally are superior to those of the south; this the author suggests may be due to their having been recruited to a much greater extent from the emigrations which have passed eastwards from Asia to the Pacific, while the foreign intercourse of the southern coast has been mainly with the inferior Australians. The mass of the people are of that negroid Melanesian race which, variously modified by Malay or Polynesian or other elements, extends from Flores eastward through New Guinea to Fiji and New Caledonia. Their religion is mainly ancestor worship, the Karwar or image of a (recently) dead progenitor being greatly venerated, for the spirit of the dead has passed into it; a man will therefore sooner sell the skull than the Karwar of his father. They dread the spirits of the dead, and some other beings not of human origin. They show much artistic taste in the ornamentation of their houses, weapons, utensils, and ornaments. They are a rude, boisterous people, with doubtful capacities for culture, though the children in the Dutch mission schools do well.

The Eastern Peninsula is partly occupied by a different race, fairer and milder, with Polynesian affinities, but their religion seems to have none of the distinguishing Polynesian characteristics, and indeed to be more rudimentary than the Papuan. Their relations with English explorers have been exceptionally good, and it is desirable (even from an economical point of view), that steps should be taken to regulate their intercourse with the whites before serious collisions occur. With our great experience much might be done in this respect, and the protection thus afforded to the people would more than compensate for interference with individual liberty. They have no political organisation, the tribes being isolated, and the power of the chiefs small; hereditary rank, though a Polynesian, is not a genuine Papuan conception, and is only found among the more advanced tribes. The level of civilisation varies: some tribes are accomplished cultivators. Their agriculture is probably a tradition from Asia; most of their plants of cultivation too are Asiatic. Other tribes are nomad, and very low in the social scale. Cannibalism is not common, and perhaps chiefly confined to war time, when the practice of head-taking also prevails.

The Malay custom of building houses on piles is general, but sometimes they are built on the ground, or perched high up in trees, as among other Melanesians.

Curious claims of sovereignty over New Guinea have been asserted, since the spread of Islam in the Archipelago in the fifteenth century, by the Malay rulers of the diminutive islands Bachian, Gébé, and Tidor. The Dutch found their own claims vaguely on the last, as being his suzerain, and have annexed the western part as far east as 140° 47′ E. But the Tidor claims never extended so far, nor indeed inland at all, being enforced only by periodical raids for tribute and slaves, which have checked civilisation and perhaps thrown it back, for there were formerly powerful fleets of Papuan pirates, and in the fifteenth century we hear of a league of 'the Papuas' with the Moluccans against the Portuguese. The Dutch rule has hitherto been little more than nominal.

Disclaiming controversy, the author points out that with the present tendency of matters in the Pacific, and the certainty that the development of New Guinea must be the work of English hands and capital, its separation from the Australian system, to which it naturally belongs, would be a grave political inconvenience, crippling the future of that system, and leading to vastly increased armaments; to say nothing of the neighbourhood of foreign convict settlements, or (if the island remained unannexed), of an Alsatia of lawless adventurers.

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2. *On North Formosa.* *By* William Hancock.

The author was resident in Tamsui for the greater part of the year 1881, and during that period had opportunities of examining the geology, flora, and fauna of the district. He described the steam geysers and extinct craters, the peculiar lava-field near Tamsui, and the various earthquake shocks which had taken place,

especially that of December 1867, when the sea retired from the harbour of Kelung, and returning in the form of two waves overwhelmed a number of the inhabitants; the towns of Kelung, Tamsui, Kimpaoli, and Pachena being all more or less ruined.

The peculiarities of the flora were touched upon, and its relation to that of the mainland of China opposite, and the island of Hainan; the richness of a temperate zone flora in the matter of flowers as compared with a tropical flora was specially referred to, and allusion was made to the remarkable floral displays in the province of Chekiang during the spring months, when the mountains exhibit many of the most conspicuous British greenhouse shrubs. The author proceeded to describe the aborigines in this particular part of the island, their manners and customs, especially the different form of tatoo in male and female, their wonderful agility and mode of hunting. Having succeeded in making friends with a chief, he was taken into the forest, hostages having been left in the hands of the Chinese. The forest presented a marvellous wealth of tropical and semi-tropical vegetation, camphor trees being specially conspicuous, and ferns, more particularly *Hymenophyllum,* clothing the trunks of the trees. The impression left by the savages was pleasant; they appeared to discriminate particularly between a foreigner and the Chinese. The prevalence of typhoons was spoken of, and the disastrous consequences entailed were described. These storms appear to have their origin generally in the sea between the Philippines and Hainan, passing up the coast of China and crossing to Japan.

The volcanic relations which subsist between Formosa and Japan on the one hand, and the Philippines on the other, were referred to, the island being described as a link in the great volcanic chain extending from Kamchatka to the East Indies.

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3. *On the Advance of the Southern Chinese.* *By* Holt S. Hallett, *M.Inst.C.E., F.R.G.S.*

The following are the chief historic facts and dates brought forward by the author:—The Chinese Emperor Yaou, who came to the throne B.C. 2356, sent the family, or tribe, of Hi to take the government of the country to the south of the Yangtsi. Kingdoms thus formed extended to the south of Tonquin, B.C. 2208.

The Annamites and Shans trace their earliest dynasties to Chinese imperial families. Their kingdoms were in existence within the bounds of the Chinese Empire before its earliest contraction. Previous to the abolition of feudalism, B.C. 246, the Empire was divided into a varying number of principalities, whose dependence varied with the power of the reigning Emperor. By B.C. 1550, owing to revolts, it had contracted to within the northern bank of the Yangtsi Kiang; and during the Chou dynasty, B.C. 1134–255, seldom included any portion of the basin of that river.

The founder of the Chou dynasty divided the Empire into seventy-two principalities, and appointed his relations as rulers over them. His elder brother left the Empire, and founded the kingdoms of Youe and Hou on the frontiers of Ssŭ-ch'uan. The rulers of the kingdoms left outside by the contraction of the Empire still hold the title of Chou that was borne by the princes of the Chinese Empire. Other evidence leads to the conviction that the Shans formed part of the early Chinese horde. M. Terrien de Lacouperie allows that over thirty per cent. of the Shan vocabulary has come from the same source as that of the Chinese.

Long before the time of Gandama, B.C. 543, the Yun Shans had founded towns to the south of Yunnan, and were pushing down the valley of the Mekong through the Yun or Karen country. These Karens, there is reason to believe, were the furthest advance party of the Chinese immigration; for a long period they ruled over the kingdom of Youe-chang (Tchen-Tching, Lin-y, or Lam-ap), and in the fourth century over Cambodia. In A.D. 431, the Yun Shans founded several cities in the valley of the Menam, and by 707 they had overrun and occupied the northern half of Cambodia.

Early in the sixth century B.C., the Mau Shans entered the valley of the Irrawadi, and drove the Burmese tribes to the southward. About A.D. 1220, they annexed Assam, and became predominant over the Shan States to the east and west of the Salween as far south as Zimmé. By the end of the thirteenth century, they had shattered the Burmese Empire, driven the Yun Shans to Chaliang (from whence the latter descended and founded the kingdom of Siam), attacked Java, Malacca, and Cambodia, annexed part of Pegu, and extended their sway over the Malay Peninsula as far south as Tavoy. From this time to A.D. 1554, Shan princes were ruling in the valleys of the Irrawadi, Sittang, and Salween, as well as in the country to the south of Yunnan, as far eastward as Cochin China.

The Laos Shans were settled in the country to the west of Tonquin at a very early date, and had already wedged themselves into the Yun country, as far south as Vien Chang, before the arrival of the Yun Shans in the valley of the Menam; they are, therefore, known to their neighbours as the Lau, or Lao, which means ancient or old.

4. *Curiosities of Travel on the Tibetan frontier.* *By* E. COLBORNE BABER, *F.R.G.S.*

In a paper illustrating the difficulty of the problems which a traveller in an unexplored country is called upon to examine, the author gave an account of the curious wax-insect of Western China, the eggs of which are transported from a valley on the border of Yunnan to a plain in Western Ssŭ-ch'uan, a distance of more than 200 miles. A great multitude of carriers—ten thousand or more in number, travelling in single file all through the night, and resting by day—convey the galls to their destination, where they are attached to trees, on which the insects deposit wax and breed. He also described, in some detail, his discovery of the singular fact that a certain kind of timber, which is used to make coffins, and is of extraordinary value on account of its resistance to the attacks of insects and rot, is found buried deeply in the soil, and is actually mined for, either by sinking shafts or by a process of 'hydraulicking.' The trunks are of great size, and a coffin made of the planks which they afford is worth some 300*l*. This valuable material is found imbedded in a hard yellow clay, which Mr. Baber suggests may be tha-till or boulder-clay. The sub-Himalayan region in question exhibits manifest traces of glaciers, by which, according to the latest school of geologists, the till has been formed.

Some remarks on an analysis of the so-called 'white copper' of Western China, and on an antelope which may have given rise to Abbé Huc's fable of the Unicorn, concluded the paper.

5. *On the Athabasca District of the Canadian North-West Territory.* *By the* Rev. EMILE PETITOT.

The author, who belonged to the Congregation of the Oblats-de-Marie French missionaries, commenced his explorations in the Canadian North-West so long ago as April 1864, continuing them from 1865 to 1873. He published a preliminary account of these in the Bulletin of the French Geographical Society for July–September 1875, which is here recast, with material additions and personal observations acquired during subsequent travel as late as 1879.

After defining the limits of the commercial district of Athabasca as settled in the latter year by the Hudson's Bay Company, and briefly sketching its great natural features, M. Petitot describes in detail the systems of the Athabasca and Peace rivers, which after uniting and entering the Great Slave Lake, take the name of the Mackenzie, and he also treats Lake Athabasca in like manner, with its connected minor lakes and smaller affluents. In doing this he corrects various errors as to the nomenclature, position, and physical features of the very complex water-system of the region, with numerous observations on its geology, fauna, flora, and native inhabitants, and indications of probable sources of future development. The chief

points are his minute details of the alterations in the course, and especially in the mouths, of the Athabasca and Peace rivers, which at the point of junction with the Slave river at the western extremity of Lake Athabasca now form vast deltas of sedimentary land, available for cultivation in a region elsewhere almost entirely wanting vegetable earth. The extremely variable hydrographic conditions are owing to an abnormal intercommunication between the three great watercourses above named, so that an excess of supply from the catchment basin of any one of them is passed over to the others. The various causes and stages of formation of new land, with the consequent development of vegetation &c., are fully explained; and the author entertains great hope (though there can be no absolute certainty on the point) that the vast reclaimed area will remain in its present condition.

In discussing the Indian tribes he refers to their great diminution from the consequences of an excessive destruction of animals available for food. The whole population of the district, including red-skins, half-castes, and whites, was in 1879 only 2,268.

An historic sketch and statistical and meteorological tables were given in this memoir, which with its accompanying map has been translated and published in the Proceedings of the Royal Geographical Society for November 1883.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION.—R. H. INGLIS PALGRAVE, F.R.S., F.S.S.

[For Mr. Palgrave's address see p. 605.]

THURSDAY, SEPTEMBER 20.

The following Papers were read:—

1. *The Cotton Trade: its Condition and Prospects.*[1] *By* EDWIN GUTHRIE.

For a number of years now the cotton trade has suffered severe depression. In spite of the improved appliances of the present day as compared with those of ten or twenty years ago, by means of which improvements the cost of converting cotton into yarn is at least a halfpenny per pound weight cheaper, the profit obtainable is less than it was, until now; simple interest is all that is generally made upon the capital employed in the trade, which is not a proper rate of compensation for all the contingencies incident to fixity of costly plant.

The following tables show the course of our trade in relation to that of other three positions of manufacture—viz., Continental Europe, the United States, and India:—

TABLE I.—CONSUMPTION OF COTTON IN GREAT BRITAIN, CONTINENT OF EUROPE, AND UNITED STATES, FROM 1836, IN AVERAGE PERIODS OF FIVE YEARS.

Years	Average whole supply in 400 lb. Bales	Absolute increase	Rate of increase per cent.	Great Britain	Absolute increase	Rate of increase per cent.	Continent of Europe	Absolute increase	Rate of increase per cent.	United States	Absolute increase	Rate of increase per cent.
1836–40	1,780,000	—	—	1,014,000	—	—	521,000	—	—	242,000	—	—
1841–45	2,350,000	570,000	32·00	1,303,000	289,000	28·50	668,000	147,000	28·21	381,000	139,000	57·44
1846–50	2,777,000	427,000	18·17	1,424,000	121,000	9·28	751,000	83,000	12·42	601,000	220,000	57·74
1851–55	3,707,000	930,000	33·49	1,875,000	451,000	31·66	1,128,000	377,000	50·20	703,000	102,000	16·97
1856 60	4,834,000	1,127,000	30·40	2,368,000	493,000	26·29	1,568,000	440,000	39·00	897,000	194,000	27·59
1861–65	—	—	—	—	WAR	—	—	—	—	—	—	—
1866–70	5,023,000	189,000	3·91	2,434,000	66,000	2·79	1,633,000	65,000	4·15	955,000	58,000	6·46
1871–75	6,525,000	1,502,000	29·90	3,071,000	637,000	26·18	2,141,000	508,000	31·10	1,312,000	357,000	37·38
1876–80	7,418,000	993,000	15·22	3,137,000	66,000	2·14	2,567,000	426,000	19·90	1,714,000	402,000	30·64
1881–82	8,902,000	1,484,000	20·00	3,626,000	489,000	15·58	3,139,000	572,000	22·28	2,137,000	423,000	24·68

TABLE II.—CONSUMPTION OF COTTON.
(*Bombay Presidency Report.*)

	Bales 400 lbs.	Absolute increase.	Rate of increase per cent.
1877–78	222,440		
1878–79 . . .	207,509	74,708	33·58
1879–80	252,260		
1880–81	297,148		

For the purposes of this writing, which are general rather than particular, these tables are sufficient. The author does not propose to burden the paper with any further statistics.

[1] The paper has been published by the author as a pamphlet (Irelands, Manchester).

These tables show several things:—

1. That the production of the world's crop has steadily increased from the first development of the trade, except during or immediately succeeding the period of the American war.

2. That the absolute quantity consumed in Great Britain has steadily increased in like manner and with the like exception.

3. That the absolute quantity used in the three other positions has also increased in like manner.

4. That the ratio of increase has been greatly in favour of all the positions except that of Great Britain.

Thus, if we have regard to the first three indications, the matter appears wholly a subject for congratulation. If we have regard to the last indication, the appearance is that the cotton trade of Great Britain does not flourish so well as that of other countries.

The growth of the trade in other countries has been assisted by the following causes: The increased facilities of transit and communication have rendered it possible for cotton to reach the point of manufacture, almost wherever that point may be, at about the same cost; thus the raw material, which formerly (so far as it was used upon the continent of Europe) was landed in Liverpool, goes direct from the cotton-growing States to the Continent, and our competitors there have not now to bear double port charges, double freights, double or treble profits *in transitu.*

The British goodwill of the business is being narrowed by the diffusion of the trade, consequent upon its being made easy to all.

Under the second head the tariffs imposed by foreign nations upon British manufactures, and the restrictions upon our own labour imposed by our Factory Acts, press adversely upon the trade in Great Britain. Under the Act of 1848 the hours of labour in cotton mills were reduced from 69 to 60, and by the Act of 1870 to 56½. The hours worked on the Continent are generally from 68 to 72, a difference of about 30 per cent.

The cost incident to the spinning of cotton may be roughly divided into five elements—viz., (1) cost of raw material, (2) cost of mills and machinery, (3) cost of power, (4) cost of labour, (5) cost of reaching the consumer.

In the first-named element we have lost the advantage we had, as before explained.

In the second we *might* have a distinct advantage, for the mills in working condition erected in England represent a value of about 1*l.* per spindle and 20*l.* per loom, while the mills of the Continent and the United States represent a value of about three times that amount; but this advantage is in great part, if not entirely, overbalanced by the number of hours worked by our competitors being much greater, thus reducing the charge per pound of production, represented under the head of rent, depreciation, and interest.

In the third we have if anything some little advantage, for coal is nowhere cheaper than in Lancashire, although, by the great economy of fuel now possible in consequence of the improvements in engines, boilers, and machinery, the relative importance of this element of cost is much smaller than formerly, and our advantage is a lessened one.

In the fourth element, labour, we are under a distinct disadvantage.

In the fifth element of cost we have no appreciable advantage in neutral markets, while within their own boundaries our competitors have an advantage in a saving of carriage.

Of these five principal elements of cost three may be regarded as rigid, and not within the control of the spinners, the two others being elastic and variable at the will of the workers. They are—(1) rent, interest and depreciation which follow the number of hours worked, and (2) the cost of labour.

The competition to which we are parties is not between labour and capital within our own boundaries, but between labour at home and labour abroad, and not wholly between English and foreign labour, but, in a great measure, between Lancashire labour at home and Lancashire labour abroad; for not only are we

constantly supplying the best machinery, but the best Lancashire hands to the mills of the Continent, the United States, and India.

The author does not wish to advocate a return of British workpeople to an unnecessary increase of labour, or any unnecessary sacrifice of the beneficial influences of properly applied leisure; but, with the facts before them, it is for the co-partnership of capital and labour to determine in what proportion they can afford to appropriate their time between labour and leisure.

It is true that for every farthing which might be saved in increased economy in respect of the elements of cost within our control, we are handicapped five or ten farthings by the protective tariffs of other countries, but *they* are not within our control, and a saving of even a farthing a pound often makes all the difference between good trade and bad trade.

It has been urged in some quarters that the remedy for trade depression is to be found in the closing of our mills one or two days a week, so as to limit supply and so stimulate demand.

In the author's opinion such a course would be suicidal, for, while it would enhance the cost of production to ourselves, it would not affect the cost to our competitors of their productions, while they would equally participate in the advantages of the advance in price. So they would be encouraged to erect new mills, and to the extent to which we had thrown our own mills out of employment voluntarily, they would have to remain closed afterwards under compulsion of the secondary effects of our own acts.

The present depressed condition of things is thus attributable to the reality of foreign competition, encouraged by twofold causes, viz., (1) the legitimate effects of improved appliances arising out of the common human advancement, and (2) the illegitimate consequence of international 'boycotting,' that is to say, protective tariffs, and of our own internal trade restrictions.

The only hope of relief lies in the economy of our work, the quality of our workmanship, our own persistent loyalty to the principles of liberty in relation to trade, and the gradual recognition on the part of other nations of the same great principle.

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2. *An Attempt at the more Definite Statement of the Malthusian Principle.*[1] *By the* Rev. William Cunningham.

1. The principle of Malthus was well founded, and soon attained general acceptance; but this leads to its being sometimes stated in an exaggerated form, and being used as an excuse for apathy in regard to human misery.

2. There must be (somewhere or other) an absolute limit to the possible production from the globe, and, as population increases steadily in many lands, the reaching of this absolute limit of possible production is a mere question of time.

3. 'Population tends to increase faster than the means of subsistence are increased.' This seems to mean more than that population is capable of so increasing, and to be a statement in regard to actual occurrences. If so it can only be proved by showing that population—where definitely observed—has tended to increase faster than the means of subsistence were increased.

4. There is no proof of this from English history, and no *primâ facie* support is given to it when we compare the growth of population in recent years with that of productive power as measured by capital, and of purchasing power as measured by our exports of native products and manufactures. The tendency to rapid reproduction must be regarded as *occult* in our own land and century. Besides, it is wise to classify our facts before we assign causes; especially is this the case when the whole question is as to the precise effect of a force, the reality of which all admit. The growth of population may be described in three propositions.

5. I. *Population has generally increased up to the relative limit set by the power of procuring subsistence at any given time and place.*

6. But skill and enterprise move the relative limit nearer to the absolute limit, and give population the opportunity of advancing.

[1] *Macmillan's Magazine*, December 1883.

7. II. *Sometimes population does not increase so rapidly as the quantity of procurable subsistence is increased.*

8. The rate of increase, when an opportunity occurs, depends to some extent on the definiteness of the organisation of the society in which it occurs.

9. III. *An increase of population while the relative limit is unaltered, necessarily implies social degradation.*

10. But is the reproductive instinct always the efficient cause of this degradation? Under certain circumstances the reproductive force appears (1) only to perpetuate, in others (2) to accelerate degradation, while in some cases it appears (3) to initiate it. Imprudent habits are not equally to blame in all cases, and the removal of redundant population or suppression of imprudent habits would not act similarly in all these cases as a remedy. The existence of a redundant population is not to be regarded as characteristic of the normal condition of human society, but as symptomatic of some special social evil, the precise causes of which, and probable remedies for which in each particular case, demand our attention.

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3. *On the Statistics of the Free Public Library, Notting Hill.* *By* James Heywood, *F.R.S.*

There are nearly 5,000 volumes in the library.

The following Table gives the Number of Readers during the Year 1882.

	Week Days	Sun-days	Total		Week Days	Sun-days	Total
January . . .	1,408	131	1,539	August (Bank Holiday)	1,236	56	1,292
February . .	1,497	157	1,654	September .	Closed	—	—
March . . .	1,232	130	1,362	October . .	1,681	111	1,792
April (Easter) .	1,096	84	1,180	November . .	1,807	225	2,032
May (Whitsun) .	1,388	74	1,462	December (3 weeks) .	1,115	118	1,233
June . . .	1,188	101	1,289				
July . . .	1,393	101	1,494				
Total . .	—	—	—	— — —	14,841	1,288	16,129

The following Table gives the Number of Volumes Lent for Home Reading in 1882.

	All Classes of Books except Fiction	Fiction	Total		All Classes of Books except Fiction	Fiction	Total
January . .	442	417	859	July . . .	422	448	870
February . .	515	478	993	August (3 weeks)	256	300	556[1]
March . .	557	576	1,133	September .	Closed	—	—
April . .	401	403	804	October . .	289	400	689
May . . .	465	482	947	November .	469	494	963
June . . .	443	485	928	December . .	303	363	666
Total . .	—	—	—	— — —	4,562	4,846	9,508

[1] All books called in.

The number of volumes lent out remains nearly the same as in former years, but a better class of books are borrowed, and fewer works of fiction.

4. *On the Evils arising from the Pollution of Rivers.* *By* General Sir J. E. Alexander, *K.C.B.*, *F.R.S.E.*

The author belonged for a number of years to the Association for the Preservation of the Rivers and Lochs of Scotland from Pollution, also to the Association for the Improvement of Scotch Fisheries.

Mr. F. Buckland's idea was to let the polluted water be evaporated in shallow tanks and to utilise the deposit. The great impediment to improvement was the want of co-operation, the proprietors of public works not finding it convenient to interfere with their tenants. The poor man cannot now afford salmon, which used to be 6*d.* a pound, and is now 1*s.* and 1*s.* 6*d.* the pound.

The author expresses his opinion that members of both Houses of Parliament should energetically take up the question of pollution, and induce the Government to frame laws, and see them enforced, to preserve our valuable waters for the health of the people and the production of fish.

Complaint is made in the paper of the loss of peoples' health by pollution of rivers, and the loss of horses from the same cause. Mr. Smith, of Deanston, near Stirling, prevented the sewage of his cotton works spoiling the beautiful Teith—a fine salmon river. Allusion is made to the successful fish-hatching at Howietown, Stirling, by Sir James G. Maitland, Bart.

There used to be only eels in the New Zealand rivers; now good baskets of trout may be caught in the colony from imported fish. Marine eel-catching is described.

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5. *On Free Libraries.* *By* Professor Leone Levi, *F.S.S.*

The President delivered the following Address:—

The post of President of this Section is one which any man who is honoured by the choice of the Council of the Association must feel considerable diffidence in accepting. There are two main reasons which lead to this. First, he sees on the roll of your Presidents a long list of names of men whose distinction he cannot hope to equal; next, he finds in the growing scope of the subjects discussed at your meetings an ever-widening field of investigation, the whole of which he can never hope to master. The very name of the Section bears witness to this extension of its subject-matter for inquiry. Established originally as the Section for Statistics, it remained under this title for more than twenty years. Extending then, and rightly, its scope beyond the limits of Statistics alone, it undertook to deal with that branch of science to which Statistics are especially useful, and became the Section of Economic Science and Statistics, the title retained until the present day. This very difference in the designation marks out the development of thought on the subject, a development which I may remark has been greatly assisted by the labours of my distinguished predecessors in this chair. Their names suggest great variety of pursuits, great difference of study, but I find one common link uniting the modes of thought of all, a desire to promote the interest of Economic Science, and a desire also in practice to promote the best interests of the Empire, by the application, where possible, of the laws of that Science to the pursuits of ordinary life. Thus, among the names of earlier Presidents of this Section, there are those of Mr. Babbage and of Mr. Henry Hallam, the latter known to the present generation as an historian of the very highest rank, but known also in his own time as taking a warm interest in all matters which concerned the social well-being of the country. Among those former Presidents who have taken a prominent and valued share in public life, are the names of Mr. W. E. Forster and the present Postmaster-General, whose connection with Economic Science is marked by the fact that he is even better known throughout the country as Professor Fawcett, than as the holder of his high office. Considerations of space will not permit me to mention many other names, but I may refer to Mr. Tooke, who in his great work on the history of prices combined so admirably statistical method with a scien-

tific exposition of results; and to his perhaps abler disciple Mr. William Newmarch, from whom I had myself the privilege to learn much, especially during the latter years of his life. Of others whom I have had the advantage of knowing, I may name Mr. James Heywood, whose continued labours in the service of the Association show that our branch of study is well to be reconciled with a calm and thoughtful life, and who keeps up a warm interest in the work of the Section over which he presided thirty years ago. My list of the more recent Presidents must close with Professor Jevons, too early lost to economic study, and Professor Ingram. I have mentioned in particular Professor Ingram's name. I well remember the enthusiastic language in which Mr. Newmarch spoke to me of his address before this Section. Bearing this in mind, I wish in the first place to bring to the remembrance of the present meeting the manner in which Professor Ingram claimed for the science of social life a place in the highest ranks as a branch of investigation.

In many respects this claim is generally conceded.

The position which Economic Science occupies in this country shows how strong is the hold it possesses over public opinion. Whether our statesmen at all times interpret its teaching accurately or not, they feel bound to profess a deference to that teaching, or at least to explain the reasons why they differ from it. And this is rightly the case. At all times since this country began to commence that remarkable development of ripening, in gradual, calm, steady progress, from what, for want of a better term, I must style mediæval, to modern modes of thought, on which it still continues, a growth, as it seems to me, unexampled in the history of any other nation, there have been among its citizens able teachers of Economic truth. Opinions expressed in the reign of Queen Elizabeth by Sir Thomas Gresham, those held during the reign of Charles II. by Sir William Petty, are current at the present time, because they are based on careful observation and sound reasoning. Our commercial policy is now based on lines laid down nearly a century since by Adam Smith. And the brilliant success which has followed the financial measures carried out by Sir Robert Peel and Mr. Gladstone results from the ability with which those statesmen applied the principles of economic teaching to the circumstances of the period with which they were surrounded. This brief summary indicates the points in which economic teaching is most sharply brought home to the minds of the majority of those who think about it at all at the present time. They do not so much think about it as a science, as in that subdivision of its study which I may best call an art. They say it has brought in free trade. They say also that while free trade has caused marvellous prosperity to this country, other countries do very well without it. Hence they doubt, on what they call practical grounds, the teaching of Economic Science.

I do not intend to enter into this controversy here, though I think there can be no doubt on which side the truth lies. But I merely use this as an illustration. If economic teaching will produce wealth, it is, many people think, worth studying on those grounds. If it will not, it is not, in their opinion, worth following. Now, while I most distinctly desire to assert that nations may, by listening to the lessons of sound economic teaching, advance their prosperity in many ways, as they have done by following Free Trade, yet we must not limit the scope of the science to investigating the production of wealth alone. We do not say that the sole object of the science of chemistry is to improve health, though the health of the inhabitants of this country has been benefited in no small degree by attending, however imperfectly, to the teaching of chemical science.

What, then, should the course of action of the careful student of economic thought be at the present time? We must not think that the study of the production and distribution of wealth alone is the sole object of Economic Science; nor, again, that everything which the science has to teach has been discovered and taught already; that we have now but to classify results, to expound to all future generations text-books which have been written by our forefathers; that the whole kingdom over which observation may extend has been explored and mapped out; that everything which can be said on these subjects has been said already. If we did this we should place ourselves entirely and hopelessly in the wrong. Even

Homer, as the fine Greek proverb has it, is not 'enough for everything.' We should, by following this course, limit ourselves in a manner which none who have sought to work in a scientific spirit have ever done in any other branch of research, and should restrict the study, the bounds of which we should desire to extend, into becoming merely a record of the past—an empty record, also, for instead of our investigation being instinct with life, it would soon become a mere series of dead reminiscences.

In saying this I am not unmindful of the very sagacious remark made by Professor Ingram, to whose discourse, delivered to this Section at Dublin, I have referred before. Speaking of political economy, he observed, 'It is the most difficult of all the sciences, because it is that in which the phenomena dealt with are the most complex, and dependent on the greatest variety of conditions, and in which, accordingly, appearances are most deceitful, and error takes the most plausible forms.' Bearing this warning in mind, and remembering the limitations already laid down as to those points which we should shun, let us proceed to consider in what direction lies the true course of economic progress.

And here I shall best point out the process through which our study may be aided if I quote from a work which, though it may not in all respects fully come up to the promise of its title, yet contains within its pages a great storehouse of genuine thought—the 'Novum Organum Renovatum' of Dr. Whewell. The first chapter of Dr. Whewell's second book, which deals with the construction of science, commences thus:—*The two processes by which science is constructed are the explication of conceptions, and the colligation of facts.* The definition contained in this statement is so clear and complete that it may almost pass for a truism. But it contains the axiom on which every science must be founded. Our own observation places before us constantly the texts of the Book of Economic Science, but, as has been well said, 'these convey no knowledge to us till we have discovered the alphabet by which they are to be read.'

Here, again, we shall do well to bear in mind the warning just quoted as to Economic Science being the most difficult of all the sciences, because, in it, error takes the most plausible forms. It is because this science deals with the facts of social life, with matters which all can observe, and consequently think themselves capable of judging, that it appears to be so easy, and in reality is so difficult.

Again, let us consider the circumstances under which the study of political economy has to be carried on. Political economy exists both as the science which solves the problems of social existence, and as the art in which that science is applied in practice to ordinary life. Now, it differs from almost every other branch of science in the fact that in it scarcely any experiment is ever possible. We cannot, to revert to a point previously mentioned, call the application of the principle of Free Trade to the financial legislation of this country an experiment. It was the work of men confident in their science; justly confident, because they felt certain, from the teachings of that science, that the act would succeed.

But since experiment cannot be tried, what course should the student follow? At this point we may with advantage glance for a moment at the two schools into which economic writers have principally shown a tendency to divide of late years—the historic and the philosophic schools. A science which deals with the facts of human life, and yet does not admit of experiment, must be the more indebted to observation. Here, we may see, is the opportunity for those who follow the historical method. But mere observation directed by no principle is unaware what facts it should gather, or how the connection of these facts should be explained. Hence the work is incomplete without the application of correct theory. This arrangement supposes the pre-existence of theory before the historical method can be applied. Endeavour to avoid the conclusion as we may, we are driven to admit that our science must be founded on theory, call it by what name you will: abstraction, which lies at the root of the deductive, or hypothesis, which forms the basis of the inductive method.

It is remarkable that in the writings of Adam Smith we may find the habits of mind exemplified on which both these schools of thought have based their reasoning. As was well observed by the late Mr. Walter Bagehot, it was precisely

this position of Adam Smith which gave him his peculiar usefulness. He fulfilled two functions. On the one hand, he prepared the way for, though he did not found, the abstract science of Political Economy. In this sense he is the legitimate progenitor of Ricardo and John Stuart Mill. On the other hand, he was also the beginner of a great practical movement, and no man can head a great practical movement without knowledge of the affairs of ordinary life. There are, Mr. Bagehot truly observes, scarcely five consecutive pages in the 'Wealth of Nations' which do not 'contain some sound and solid observation, important in practice and replete with common sense. The most experienced men of business would have been proud of such a fund of just maxims fresh from the life, and it is wonderful that they should have occurred to an absent student, apparently buried in books and busied with abstractions.' It is somewhat strange that the opposite qualities as to habit of mind are traceable in David Ricardo. He was the founder of abstract political economy, but his occupations were the reverse of those in which it might have been expected that such modes of thought would be encouraged. He was a shrewd, active man of business, constantly engaged in a very absorbing occupation. It is the fashion rather to decry Ricardo at this moment, but I think that those who desire to advance economic study among us may do well to fortify themselves by a study of his arguments, though they may not be able to accept all his conclusions.

I have endeavoured, in what has been said thus far, to explain the principle of research by which we may hope to extend the bounds of the branch of science which we study, and the habits of thought we should desire to cultivate. We must follow the historical method of research, too little recently followed in this country.[1] We must test economic conclusions by the evidence of facts. But while we thus accept the necessity of following a deductive method, we must bear in mind that it is not opposed to, but can only safely be carried out on the lines marked out by, inductive reasoning. Nor do I, in speaking thus of the historic method, wish to be understood to endorse without reserve the views of the historic school. But though I think in some respects their conclusions are incorrect, I can well believe that research carried out on the historic method, based on sound principles, would be very fruitful in results. It is rather, however, the art than the science of economics which has a hold on the popular mind at this moment. We must not overlook this feeling.

In active, busy, hard-working England we are too much apt to neglect any mode of research from which we do not see immediate, marked, and tangible results. We shall do well to turn this habit of mind, if we can, into the service of economic inquiry. There are several branches of economic study, the investigation of which might be useful to our country at the present time. I will venture to indicate two or three of them.

First, it is the opinion of some observers of contemporary events—men competent to form an opinion, from habit of mind and opportunity of observation—that the days of exuberant prosperity to this country—the days in which, to use an expression now historic, prosperity advanced 'by leaps and bounds'—are over. I shall not pause now to examine into the grounds upon which this opinion is founded. I do not intend to put it forward in an extreme sense, as if I believed it possible that all the brilliant and luxuriant growth of vigorous power by which we are surrounded is about immediately to pass into the 'sere and yellow leaf,' and to fade away at once. But it is, I think, quite possible, without expecting any change as marked as this to come on immediately, that the days when great profits were made by large and important classes in the community may be over. There may be and there probably are great inventions yet to be discovered, as great—possibly even greater—than those which have changed the face of this country, which

[1] I should, in passing, refer to Mr. James E. Thorold Rogers's work, *A History of Agriculture and Prices in England from the Year after the Oxford Parliament*, 1259, *to the Commencement of the Continental War*, 1793.' Vols. i. to iv. 1259–1582. Oxford: Printed in the Clarendon Press. London: Oxford University Press Warehouse, 7 Paternoster Row.

enable it to bear on its surface a population far more numerous and yet, on the whole, more prosperous than has ever yet, at any previous period in our history, been numbered within the four seas. But yet there does seem a pause—perhaps only for the time—in the progress of several branches of industrial labour; and we may be not very remote from, if we are not already entering into, the condition termed by economists the non-progressive state. I do not dread this condition for our country, should it arrive. We may, under it, by a judicious adaptation of habits to the circumstances of the case, be powerful, prosperous, and respected by our neighbours. Countries in this condition have gone on for years in great prosperity, supporting their population in a state of marked comfort. But when they have done so, it has been by a distinct acceptance on the part of the popular mind of obedience to the common virtues of thrift and foresight which have been too long neglected among us. Here is a practical field of great usefulness for the economic student to occupy. Some have already laboured in it. It will be far better for our population if they can be brought to anticipate what must result from such a state of matters, rather by calm reasoning than by the stern teaching of necessity. This is one point of the application of the art of economics which may be very usefully followed out in a scientific spirit.

There is another position of a most useful character which may well be occupied, which requires knowledge somewhat of a different order. It is remarkable, at the present time, how little foreign economic writers are studied in this country. You may read through the works of more than one recent English writer on economic subjects almost without being aware that there existed any authors dealing with the subject except those who employed the English language. There does exist, however, as I need hardly mention, a very copious and valuable literature, the work of Continental scientific writers, which we might do well to explore and to master. Some foreign writers—or, at least, some of their works—have been translated into English. Thus, the very useful 'Guide to the Study of Political Economy,' by Dr. Luigi Cossa,[1] has been translated from Italian into English, and has been published here, with a preface by the late Professor Jevons. Again, the two valuable volumes of the 'Principles of Political Economy,'[2] by Professor Wilhelm Roscher, have been translated into English, and are a welcome addition to our stock of information. This work is rendered, and very ably too, into English. I must confess that it is a matter of some regret to me that this translation has proceeded from an American source. Not that I would grudge my fellow-students in the United States the distinction of the work; but I well remember the difficulties which environed a proposed translation in England, which I sought to carry out, and that the matter was dropped, those difficulties for the time proving too great to be surmounted. I hope that greater interest in these subjects might be felt now. I think that if some intelligent students of economics in this country would attempt a series of translations from the works of foreign writers, not yet known here, they might do themselves and the science itself a service. Something has been done in this direction, but there is still a wide field to occupy. I may quote, in saying this, a passage very much to the point from Professor Jevons' preface to Dr. Luigi Cossa's 'Guide,' which I have just mentioned:—

'Every economist would grant that we have in English the works of the father of the science, Adam Smith, and of not a few successors or predecessors who have made the science almost an English science. But this fact, joined perhaps with the common want of linguistic power in English students, has led our economic writers to ignore too much the great works of the French and Italian economists, as well as the invaluable recent treatises of German writers. The survey of the foreign literature of the subject given in this "Guide" will enable the English

[1] *Guide to the Study of Political Economy.* By Dr. Luigi Cossa. London: Macmillan & Co.

[2] *Principles of Political Economy.* By William Roscher, Professor of Political Economy at the University of Leipzig. Translated by John J. Lalor, A.M. London: Trübner & Co. 2 volumes.

student to fix the bearings of the point of knowledge which he has reached, and to estimate the fraction of the ocean of economic literature which he has been able to traverse.'

To take a third point. Every successive generation, perhaps almost every decade, is, as a rule, occupied with some particular branch of economic thought. A short time since Free Trade was the economic point occupying the thoughts of all. Everything almost was referred to a Free Trade standard, and was judged accordingly. For a long period, also, there came into prominence the great doctrine of *laissez-faire*. The late Professor Jevons, who joined to vast logical and analytical powers of mind a vigorous common sense, which perceived as it were by intuition that when once an economic doctrine of that class became separated from the sphere of practical application it ran a great risk of becoming entirely vague and indefinite, has done more than anyone else to mark out the limits within which that doctrine should be applied. After this the relation of Socialism to economic teaching became, and is now, one of the important questions of the day.

The vigorous periodical literature of the time, which has taken the place held by pamphlets to our fathers and grandfathers, supplies a fairly good test of the subjects which occupy the public mind; and it is a proof of the prominence now given to Socialism that the numbers published in April last of the 'Contemporary Review,' the 'Fortnightly,' and the 'Nineteenth Century,' all three contained articles bearing on this subject, as did also the July number of 'Macmillan's Magazine.' Those in the 'Contemporary' and the 'Fortnightly' were written by M. Emile de Laveleye, the eminent Belgian economist; that in the 'Nineteenth Century' was written by the Rev. Samuel A. Barnett, a well-known hard-working clergyman in the east of London; the article in 'Macmillan's Magazine' was written by Mr. Fawcett as a chapter in the new edition of his 'Manual of Political Economy.' The views of the subject presented by these writers differ greatly, as may be imagined, from each other. M. de Laveleye presents to us the aspect under which Socialism appears on the Continent. He admits that the material condition of the population is preferable to what it was in the Middle Ages, but he looks with great uneasiness to the state of matters in an age in which competition rules everything. General dissatisfaction with his lot is the result, M. de Laveleye thinks, to everyone, with a feeling of want of security as to the future. It is not the case that the condition of working men is worse than it was formerly. They have benefited from the greater cheapness of manufactured goods, they are in many places better housed, they are generally better clothed, and their furniture is better. But it is the sight of the inequalities existing in modern life, the loosening of the ties which formerly united class with class, which induces the bitterness of feeling closely allied with Socialism, Anarchy, and Nihilism, and causes the desire for 'the destruction of everything, states and churches, with all their institutions and their laws—religious, political, judicial, financial, educational, or social'—like the 'Fifth Monarchy Men,' whom we read of during the darkest years of the Commonwealth. Universal destruction is the watchword of this party, that a new world may be built on the ruins.

M. de Laveleye, while commenting on these matters, does not apprehend any immediate danger to the present social order, unless one of those great crises takes place in which there is a general collapse of power, such as occurred after the break-up of the late Empire in France. The world saw then what the deeds of the Commune were. May it be long before such an outburst of crime is witnessed again. But when we consider the existing condition of affairs among the principal nations of Europe, the severe strain of forced military service, the heavy demands on the means of the people to meet the requirements of the crushing debts, national as well as local, the vast budgets, out of proportion to the benefits received therefrom by the people who pay the taxes, and the increasing weakness of administrative power—much as one may regret that such turbulence of spirit exists—one cannot wonder that it should spring up. This is a rough sketch of the view presented by M. de Laveleye.

In our own country these questions usually take a milder form: though I could find expressions of opinion as strong, or nearly as strong, to lay before you, as those

just quoted. But I prefer to take for my instance the gentler type of opinion as shown in the article by the Rev. Samuel Barnett in the 'Nineteenth Century' to which I have referred. England is, perhaps I should say, has been, honourably distinguished as a country in which the 'falsehood of extremes' is instinctively felt. We have here no crushing conscription, no inordinate pressure of taxation. Hitherto we have fortunately escaped these things, and may, by the exercise of common sense, hope to do so in future. Mr. Barnett feels this. His recommendations include a wiser administration of the Poor Laws, so as to enable a distinction to be drawn between the man who had kept clear of parish relief up to a reasonable age, and the man who had not. This, and a wider application of the principle of the Artisans' Dwellings Act and the Libraries Act, are amongst the principal of his recommendations. They come to this, that the old age of the honest working man should be made secure against distressing want or degrading relief, and that the power of obtaining rational pleasures should be provided for him within reasonable bounds. Some will think this would be going too far. The question for the economist to consider is, How far can it be granted without impairing the great principle of self-help? This is a point too frequently ignored; but when I consider the condition of many of our working classes, their prospects in this country, and the openings which our colonies and the United States promise to energetic industry, I think we must be prepared to offer better terms than we hitherto have done to those who continue to dwell here.

Legislation, conceived in a somewhat similar spirit, has recently been determined on in the German Empire; and if the iron spirit of Prince Bismarck has felt it needful to yield this concession to popular feeling, it would not seem improbable that other statesmen may have, willingly or otherwise, to travel in the same road.

There are limits, however, to the application of this class of payments by the State which must be borne in mind. And Mr. Fawcett in his article in 'Macmillan's Magazine,' which deals with the thorny subjects of State Socialism and the Nationalisation of the Land, is careful to enforce this warning. The real incentive to labour and economy is individual interest, and we must be careful not to break down the force of that power, the mainspring of progress; nor to lose sight of the great principle previously referred to—which not a little in recent legislation and public feeling has powerfully tended to impair—that self-help is beyond all question and comparison the best help.

I have in these observations only marked out some of the limits of this wide subject. The question how far the principles usually included under the denomination of Socialism should or should not be taken into consideration by the State is one which our economists would do well to consider. Economic teaching is sometimes termed hard and cruel by those who do not comprehend its scope, because some of the warnings it gives do not fall in with the sickly slackness of popular sentiment. This is most unjust. Other branches of study are not spoken of in the same manner. The surgeon is not termed cruel because he recommends an operation which, though painful, is essential to life; because he shows that the neglect of certain precautions will be followed by suffering, perhaps by death. The economist, who sees that the happiness of the community can only be secured by causing individuals to submit to restraints which are irksome and perhaps painful, should not be termed cruel for pointing out what is essential to the general well-being. He is, in this, entirely within the scope of his duty. A community which is not prosperous can scarcely possess all the elements essential for happiness.

I have endeavoured to indicate in these remarks both some of the directions in which I think that economists may labour with advantage, and the principles on which their labours should be conducted. Economic science, like all other branches of science, is governed by certain laws. These laws must be adhered to, though it may not be possible to affirm of them that they are always more than relatively true. But the question of relative truth opens the door to a far wider field of inquiry, the threshold of which I must not cross.

If I may for one moment in concluding diverge from the stricter mode of

thought which I have sought to follow, I may claim for economic teaching that it is the natural utterance of the most fervent patriotism, and possesses the sanction even of a more serious authority. It was not, we may be sure, without wise deliberation that the authors of the noble English liturgy, following in this older forms of religion, included among its formularies a supplication that the monarch may study to preserve the people in wealth, taking the word in its widest sense, among other blessings. Without the means of well-founded prosperity there is no permanence for a nation. In listening to or departing from the teachings of economic truth lies the choice between the paths which lead to wealth or to want, to death or to life. Some may say there are higher aims even than these. To them I may quote the words of one of our deepest thinkers—'the virtue of prosperity is temperance, the virtue of adversity is fortitude.' It is the glory of economic teaching, while pointing out the methods by which prosperity may be secured, never to lose sight of the principles by which temperance is attained, and temperance is essential to fortitude, able to resist the hasty gusts of popular feeling, able also to warn the powerful when that feeling is well founded.

Ill will it be for England if, in times of movement, this temperance, this more than golden moderation, be not unwaveringly held in mind and observed. Well will it be for her, at such a time, should she follow the counsel of the greatest of living poets—

Not clinging to some ancient saw;
Not mastered by some modern term;
Not swift, nor slow to change, but firm;
And in its season bring the law.

FRIDAY, SEPTEMBER 21.

The following Papers were read:—

1. *Canada, as it impresses and influences an Emigrant, with Notes on the North-West Territory. By* HARRY MOODY.

There are some superficial phases which first strike a new arrival in Canada, such as the size of the country, the geniality of the climate, at any rate in summer and autumn, and the excessive untidiness of the whole country. As to *climate*, 'that true north' is not north at all; the northern sailing circle will bring you on your voyage within 300 miles of Greenland, but the Straits of Belleisle are in the same latitude as London, while Toronto is on the parallel of Florence. The *size* is difficult to understand, but the facts that New Brunswick is nearly as large as Ireland, and that Montreal is 333 miles from Toronto, give a rough and ready scale of size and distance. From the Straits of Belleisle a schooner can pass through Canadian waters to Port Arthur on Lake Superior, a distance of 2,300 miles. The character and demeanour of Canadians is unlike that of citizens of the United States, but it is very un-English too. In an English country town or village the man of the lower or lower middle class has no influence in the working of the ordinary political, parochial, or religious life, but the same man in Canada is soon taught to feel that he has a voice in the municipal government of the country, and finds himself in an atmosphere saturated with politics. He is probably in a position to earn a good living, but if he misuses his chances there is no Poor Law to fall back on; broadly speaking, the State does not stand between a man and starvation, and there is no class to be compared with the 800,000 persons receiving parish relief in Great Britain. In each district of Canada there is a carefully arranged municipal system which works in with the Provincial Government, as that again supplements the Dominion Government. *Education* is managed by the Provincial Government. The school is practically free to all, and the education on

the whole is good; considering the distances over which population in Ontario is scattered, it is surprising to find that only 2 per cent. of children of school age are returned as not attending any school. The new licence law fixes 4 per 1,000 as the maximum number of licences, and one more for every additional 500 inhabitants; but the inhabitants of any polling subdivision have the power of preventing the issue of any particular licence, or, by a three-fourths majority, the issue of any at all. Taverns are closed at 11 P.M.; on Saturdays at 7 P.M. Spirits have been the common drink of Canada, but the amount consumed has declined from 5 gallons to $1\frac{1}{2}$ gallon per head, and lager beer is taking the place of spirits. The revenue of Canada for the year ending June 30, 1883, will be about $35,600,000. To this, the Consolidated Fund revenue, may be added some $1,500,000 derived from land sales: or a total of $37,000,000. The expenditure will have been about $28,600,000. This does not look like bankruptcy. The total value of imports for the year ending June 30, 1882, was $119,000,000, and of exports, $102,000,000. Last year, 67,000,000 letters passed through the Post Office; the deposits in savings banks were $13,700,000, and the withdrawals only $10,000,000. There are 1,260,000 tons of shipping on the Dominion register; the fish products of 1882 were worth $17,000,000, and the exports of agricultural produce amounted to $35,000,000. When the Dominion was first organised the construction of the Intercolonial railway from Quebec to Halifax and St. John, New Brunswick, was an essential condition of the terms of union; and when the Dominion stretched out to absorb the little-known prairie and take in British Columbia, a trans-continental railway through British territory became a paramount necessity. Its construction within ten years was promised to British Columbia when she entered the Confederation—a promise which could not be fulfilled, though the Government set to work at once on surveys and on the construction of two important sections; but at length men were found who formed the Canadian Pacific Railway Company, and undertook the responsibility of financing the vast scheme, and surmounting the physical obstacles; the length of the main line from Montreal to the Pacific coast will be 2,875 miles; of this the Government have built or are building 650 miles, and 1,450 of the remaining 2,220 miles will be completed by the Company before the end of the season. It opens up a prairie which is, both as regards surface and fertility, as varied as it is vast. There is an immense extent of land which will grow for years without manure 25 to 35 bushels of wheat per acre; and there are millions of acres over which, for the present, it may be more advisable that sheep and cattle should roam; and the railroad will bring from British Columbia all the lumber that is required for building. Hundreds of miles of the West near the Rocky Mountains are underlain with beds of coal, the quality of which is excellent. They have thus as good or better land for settlement in Canada than in the States; and instead of immigrants, or their own inhabitants, being tempted to the Western States, they will retain their own population and keep under British rule those leaving the old country. Immigration in itself serves as an encouragement to their home manufactures, but on this delicate point it need only be said that Canada's fiscal policy has not been hurtful to England. Imports from Great Britain were $37,400,000 in 1878, and had risen to $50,500,000 in 1882, while those from the United States had fallen from $48,600,000 in 1878, to $48,200,000 in 1882.

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2. *A brief Chronological and Statistical Review of the Past and Present of Canada.* *By* Cornelius Walford, *F.S.S.*

The author commenced with a brief sketch of the early history of the Dominion from the time of its discovery by Cabot, tracing the rise of French influence, and the aggrandising policy which led to its clashing with British interests in other settlements. By the treaty of 1763 the whole country came finally under British sway, and its subsequent history is mainly occupied by the attempts at the confederation of its various provinces. These are (1) *Lower Canada,* containing about a quarter of a million square miles, being the old French

possession, with Quebec and Montreal; (2) *Upper Canada,* lying south-west of this, and containing about 100,000 square miles; (3) *Newfoundland,* an island whose fisheries render it important; (4) *Nova Scotia,* settled by the Scotch in 1622; (5) *New Brunswick,* formerly a district of Nova Scotia; (6) *Prince Edward Island,* formerly in the possession of France; (7) *British Columbia,* which was not practically opened up until the time of the gold fever in 1858; and (8) *Manitoba,* formerly a portion of the territory belonging to the Hudson's Bay Company, and ranking as a province only since 1870. The area of the Dominion is $3\frac{1}{2}$ million square miles, equal in extent to the whole of Europe. The Confederation, commenced by an Act of Parliament in 1867, embraced in 1872 all the provinces with the exception of Newfoundland, which still remains aloof. Canada in its climate reaches greater degrees of heat and cold than Europe, the thermometer ranging between 36° and 102° Fahr. The prevailing winds are N.E., N.W., and S.W.; and its pleasantest season the autumn, late in which what is known as the 'Indian Summer' occurs. The lakes are both numerous and important, several being over 1,000 miles in circumference, and in parts unfathomable.

The author gave a description of some of the principal rivers, including the St. Lawrence, the Ottawa, the Saguenay, and the Saskatchawan. It is estimated that the solid content of the first of these is 1,547,792,360,000 cubic feet, which would form a cube of water 22 miles on each side. The curious formation of the bed of the Saguenay river, which lies 600 feet below that of the St. Lawrence at their juncture, was also adverted to.

Canada contains thirty-seven cities with populations exceeding 5,000. Quebec, formerly the first in this particular, is now surpassed by both Montreal and Toronto, but continues, from its situation, the chief shipping port of the Dominion. Montreal (Mont Royal) was formerly the depôt of the fur trade; it has now, among other buildings of importance, that monument of railway enterprise, the Victoria Bridge. Toronto, the old capital of Upper Canada, is now the second city of the Dominion, and from its rapid rate of progression promises soon to take the first position. It is the great centre of the West of Canada Railways.

The agricultural statistics show an increase of landowners during the last half century, which must be compared with other newly settled countries, since in accordance with the Old World rate of progression it could only be denominated 'marvellous.' In 1831 there were 57,891 proprietors, while in 1881 the number was 588,973, and the acres owned, 67,645,162, by far the greater number of which were in plots containing between 50 and 200. The yield of wheat in 1880 was over $32\frac{1}{4}$ million bushels; of barley, over $16\frac{3}{4}$ million bushels; of oats, $70\frac{1}{2}$ million bushels; potatoes, over 55 million bushels; turnips, nearly 40 million bushels: and apples, over 13 million bushels. Butter was made to the extent of 103 million pounds; and maple sugar to that of $20\frac{1}{2}$ million pounds, whilst the returns of honey, cheese, home-spun cloth, flannel, and linen testify to the extraordinary industry of a by no means large population. The statistics of live stock show that in 1881 there were in stock enough sheep to provide for two years' consumption, cattle for nearly four, and swine for one.

The following table shows the magnitude of the export cattle trade of Canada and its increase of late years:—

	Number exported		Value in dollars	
	1875	1882	1875	1882
Horses	4,382	21,006	460,672	2,358,887
Horned Cattle . .	38,968	62,337	823,522	3,285,452
Sheep	242,438	311,669	637,561	1,228,957
Swine	16,779	3,263	152,252	10,875

The swine are now slaughtered and salted before being exported. One other branch of Canadian industry, the fishing, has been rendered of prominent interest, not only from its inherent value, but from the disputes it has occasioned. Under the Washington Treaty the Government of the United States were adjudged to pay an annual rental of 100,000*l.* for the right of free fishing in Canadian waters, and the value of the catch to the colonists in the year 1882 was over $3\frac{1}{4}$ million, exclusive of that in Manitoba and the North-West territories, from which there are no returns. The United States and Great Britain are the largest consumers of Canadian fish, in the catching of which 60,053 men and 31,574 ships and boats are employed. With over a million square miles of timber land to be reduced, the lumbering trade, which includes all operations from felling and rafting to sawing and shipping, may be considered one of the most important in the Dominion. British Columbia alone in 1880 is reported to have produced 200 million feet of prepared timber, the greater part of which was exported to California.

In mineral wealth Canada has not ranked very high at present, although its reputed gold deposits attracted its first settlers as far back as 1576. Much remains to be done in the way of facilitating conveyance before the richest region, the Rocky Mountain section of British Columbia, is opened up. In 1882 the returns gave for gold, 70,015 ounces; silver, 87,024 ounces; iron, 223,057 tons; coal, 1,307,824 tons; and crude petroleum, 15,490,622 gallons. Salt, fortunately for the fishing industry, is found in large quantities, as also is granite and building stone.

The consideration of the fur trade occupies us more with the past than the present; with the reign of Charles II., and the rivalries of the Hudson's Bay and the North-Western Companies, than with that of Victoria. It is decreasing rapidly, the exports in 1871 being valued at $1,633,501, while those in 1881 are but $987,555.

The author, quitting the consideration of the natural productions, then touched upon the prominent manufacturing industries. He showed that the amount of capital invested had increased between 1871 and 1881 from nearly 78 million dollars to over 165 million, that the aggregate value of productions had increased from $221\frac{1}{2}$ million dollars to nearly 310 million, and that the number of persons employed had increased in the decade from 187,942 to 254,935, and their average wage from 217 dollars to 233 per annum.

As may be conjectured, Canada, as a maritime nation, takes a foremost position; only four other countries in the world possessing a larger mercantile marine. During the last three years, however, this important source of national wealth has shown signs rather of retrogression than of advancement. In 1878 the total number of vessels registered in the Dominion was 7,469, with a tonnage of 1,333,015 tons, whilst in 1881 the number was but 6,412, and the tonnage but 1,156,941 tons. It must not, however, be imagined that trade has in any way followed in the wake of shipping; the following returns for the same period showing how great has been the progress:—

Year	Total exports	Total imports	Entered for home consumption	Duty
1878	$ 79,323,667	$ 93,081,787	$ 91,199,577	$12,795,693
1882	$102,137,203	$119,419,500	$112,648,927	$21,708,837

The author, referring to the protective policy of Canada which came into force in 1879, showed, by statistics, its influence on the trade, and drew therefrom the deduction 'that the exports from Canada to Great Britain have remained nearly stationary, while the imports from Great Britain to Canada have very largely increased, whereas with the United States the operation has been entirely reversed.'

The population of Canada, which in 1871 was 3,635,024, had in 1881 reached 4,324,810, being an increase in the ten years at the rate of 18·98 per cent. Of these the French settlers were in a considerable majority, the remainder being Irish, English, Scotch, Germans, Indians, and Africans. The averages of all the provinces give 1·24 persons to a square mile; 513·8 acres to a person; and 503 acres of unoccupied land to a person. The married numbered 1,380,044; the widowed 160,330; and the unmarried (mostly children), 2,784,396. The proportion of sexes is now nearly equal. According to religious denominations the population is divided into many sections. The Roman Catholics are by far the largest body, having 1,791,982 members, and the Presbyterians next, with 676,155, while Pagans can boast of 4,478, and Unitarians close the list with 2,634. There is no State Church in the Dominion. The emigrants who are daily thronging into the country seem in their social status to be undergoing change; formerly there were many more labourers, fewer mechanics, and also more farmers.

The climate of Canada, as the author pointed out, renders railways a necessity; and, after alluding to the various lines in progress, he summed up, in the following figures, their present position:—

1882. Miles open, 7,530½; number of passengers, 9,352,355; tons of freight, 13,575,787; earnings, \$29,027,789; working expenses, \$22,390,708; paid-up capital, \$415,611,810; increase per cent. of passengers over those in 1881, 34⅗ per cent.; increase per cent. of freight over that in 1881, 12½ per cent.

The canal system, so necessary for the navigation of rivers containing rapids, as do most of those in Canada, is now being superseded by railways; the decrease in passengers during the past five years being nearly 36,000 per annum, and the tons of freight being nearly 200,000 per annum.

The school laws, though varying in the provinces of Quebec and Ontario, provide for the efficient education of the rising generation, the returns showing that nearly the whole population between the ages of five and sixteen are attending school. In 1797 a grant of 500,000 acres of unoccupied lands was set apart for the establishment and endowment of a university and four foundation grammar schools. Among the items of educational outlay is included that of the post office; and here the author, in concluding, showed how greatly, and with what rapid strides, the system in Canada had advanced. The number of letters carried in 1868 was 18,000,000; owing mainly to a reduction in the rate, in 1870 it had increased to 24,500,000, and in 1882 to 56,200,000, whilst the package post had kept pace with that of the letter. The revenue was over \$2,000,000, and the expenditure nearly \$2,500,000, this being (as the author pointed out) owing to the cost of conveyance in unsettled districts. Since June 1, 1882, newspapers and periodicals printed and published in Canada, and posted from the office of publication, have been carried free—a step very obviously in advance of any European nation.

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3. *Recent Changes in the Distribution of Wealth in relation to the Incomes of the Labouring Classes. By* Professor LEONE LEVI, *F.S.S.*—See Reports, p. 353.

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4. *On the Number of the Deaf and Dumb in the World. By* WILLIAM E. A. AXON.

A rigidly accurate estimate of the total number of human beings incapable of speech is impossible. Many congenital deaf mutes will escape classification in their earliest years, as parents will not recognise the unpleasant truth until doubt is no longer possible. The proportion of deaf-mutes to the ordinary population varies in different countries, but appears to be on the average about one in every fifteen hundred. Taking this as the basis minimum, Guyot in 1842, when the

population of the globe was supposed to be 850,000,000, considered that the number of deaf-mutes then living was 600,000.[1] Since that date there has been a large increase of population, and in the extent of our knowledge as to the number of the dwellers upon the earth. Messrs. Behm and Wagner in 1875 estimated the population of the earth to be 1,396,843,000.[2] Accordingly, in the following year, taking the figure at fourteen hundred millions, the present writer, accepting the proportion previously employed by Guyot, calculated the deaf-mutes in the world to be 933,000.[3] It seems to be desirable to renew such estimates from time to time, as they are useful and convenient, if it be remembered that they should only be regarded as roughly approximating to the probable facts of the case. The latest detailed estimate of the population of the globe is that given by Mr. H. P. Hubbard.[4] In this estimate the important results of the latest of the American census and similar recent enumerations are included. Mr. Hubbard calculates the total population of the globe to be 1,623,178,161. We may therefore suppose that the number of deaf-mutes in the world is now 1,082,132. Supposing they were all congregated, the city of silence would be more than twice the size of Manchester and its immediate districts.

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5. *On the Palestine Channel and Canal Scheme.* *By* Cornelius Walford, *F.S.S.*

The author claimed for the question of the Palestine Canal consideration rather as of national import, than as belonging to the region of party politics, and traced the financial history of the present canal, showing that, though constructed at a nominal cost of 19,000,000 sterling, the sum of 52,000,000, or as 'some well-informed people' think, 70,000,000 sterling, has been the probable expenditure; that of this nominal capital England, at a cost of over 4,000,000*l.*, has secured one-sixth of the shares, which, though now bearing interest at only 5 per cent., will in 1894 receive the regular dividends; and that in return for this large financial stake in the undertaking, this country possesses in the control but 22 votes against an unlimited number of French ones. The tolls exacted are 10frs. per ton of cargo and 10frs. per passenger, plus pilotage dues; and to the aggregate collected, British ships contribute 80 per cent., against 9 per cent. French and 4 per cent. Dutch, whilst the value of our shipping passing annually through the canal is 12,000,000*l.*, and that of the cargoes they carry not less than 40,000,000*l.* The existing canal is about 100 miles long; from 190 to 320 feet wide on the surface, and 72 feet at bottom, and 26 feet deep. The block system is employed in its navigation; the grounding of a vessel causes the immediate cessation of the traffic in both directions; all vessels, unless on mail service, have to anchor during the night; and from these and other causes, among which may be included the action of pilots and the obstruction of dredging machines, a passage which could be easily accomplished in seventeen hours takes on an average forty hours, and frequently much longer.

While admitting the advantages of this waterway, which has reduced the sailing distance to Ceylon by one-half, and to Bombay by more than one-third, the fact is becoming every day more apparent that the canal is inadequate to the demands of British commerce alone. In answer to the question, What is to be done? four remedies have been suggested, of which two principally received the author's attention. The first of these, viz., a second canal alongside the existing one, has gained the approbation of the British Government. This, however, requires 'an outlay, by way of loan to the existing company, of 8,000,000 sterling at $3\frac{1}{4}$ per cent. interest.' The right of control also is to remain in the same hands;

[1] Guyot, *Liste Littéraire Philosophe*, p. 341.
[2] Behm und Wagner, *Bevölkerung der Erde.* Gotha, 1875.
[3] *American Annals of the Deaf and Dumb*, vol. xxi. p. 253, October 1876.
[4] Hubbard, *Newspaper and Bank Directory of the World.* New York, 1882.

and though a considerable reduction is to be made in pilotage and other transit dues, this is to take place only on an increase of the dividends to 21 and 23 per cent., which cannot be in the near future, seeing that the increased charges laid on the capital account (for interest on borrowed capital and the provision of a sinking fund), will materially affect them.

The second scheme adverted to is the one known as the 'Palestine Channel,' by which it is proposed to join the Mediterranean and Red Seas by means of the Jordan Valley connected with these respective seas by short canals. The canal commencing at the head of the Gulf of Akabah (the northern and shorter horn of the Red Sea) would be cut through a district partly marsh partly mountain, of 42 miles long, to the southern extremity of the Jordan Valley, and thence the remarkable depression, 1,300 feet, in which lies the Dead Sea, would provide it with a natural, convenient, and inexpensive bed of nearly 100 miles in length, and with a width of between 3 and 10 miles. Through this valley, from the Lake of Tiberias to the Dead Sea now flows the river Jordan, and towards its northern end another valley branches out in a north-westerly direction, and provides a suitable situation for a canal as far as the plain of Esdraelon, across which a cutting may be continued (taking advantage of the little River Kishon) 25 miles long, into the Bay of Acre and the Mediterranean Sea. This bay, as well as that of Akabah, are of good depth, require few engineering aids to render them navigable, and are naturally well protected. In all, as far as can be ascertained by the imperfect surveys already made, the canal must be 200 miles long, 65 of these requiring to be cut; and Tiberias and some 300 square miles of land must be submerged at a cost for compensation estimated at 1,000,000*l*. In touching on the political aspect of the question the author declared himself in favour of a Universal Protectorate. Until the proper surveys are completed no estimate can be made as to cost, but the author was strongly of opinion that the scheme presented no insuperable difficulties, and would eventually prove one of the greatest triumphs gained in the cause of commerce.

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6. *The English-speaking Populations of the World.* *By* HYDE CLARKE.

Mr. Clarke proceeded to consider the weight of the elements contributing to the influence of the English language and the populations which speak it in relation to the late censuses. The census of 1880 for the United States had given a figure of 50,000,000; that of these islands in 1881 35,000,000. Including other portions of the empire he made a total of 100,000,000 of English-speaking people. He observed that the phrase English-speaking had latterly superseded that of Anglo-Saxon, the object being to get rid of possible jealousies of race, and to place the basis of unity on language, as the expression of common culture and common institutions. He illustrated the gradual growth of the English-speaking populations in the North American regions of Canada, the United States, and West Indies at the respective censuses. The total had risen from 6,000,000 in 1800 to 56,000,000 in 1880. The consequence was not only a great expansion in this region, but a displacement of the relative proportions between North America and these islands. In 1800 North America stood 6,000,000 against 16,000,000 here; in 1850 the proportions were about equal, but since then the preponderance of America has been increasing, and now the figures are 56,000,000 against our 35,000,000. This must be the forerunner of a greater movement as the literary status of America advances. The effect of literature and journalism in promoting the common sympathy which has of late manifested itself throughout the populations was referred to, as well as the establishment of a more cordial feeling. A comparison was instituted with other languages, as Chinese, 250 millions; English, 100; Russian, 85; German, 60; Spanish, 46; French, 43; Japanese, 35. Reference was made to the measures which are in contemplation or in progress for promoting a closer intercourse among the 180,000,000 speakers of the Germanic languages. In accounting for the influences affecting the promotion of a better feeling in North America, the proceedings of the St. George's Societies of the

United States and Canada in their North American Union were noted. Mr. Clarke concluded by enforcing the value of the English language in promoting civilisation and freedom among the nations of the globe.

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7. *Agricultural Statistics. By* W. Botly.

The decade, 1872 to 1882, returns show, in Great Britain and Ireland:—

Crops.

	In the decade	Acreage
Corn crops	Decrease	1,078,049
Green crops	Decrease	363,737
Flax, hops, bare fallow, uncropped arable, clover, and artificial grasses under rotation, permanent pasture, exclusive of heath and mountain	Increase	1,441,786
Orchards and gardens	No return since 1872	—

Live Stock.

	In the decade	Number
Cattle	Increase	113,912
Sheep	Decrease	4,798,422
Pigs	Decrease	221,505
Horses used in agriculture	Increase	97,058
but since 1880	Decrease	24,363

Imports of Cattle, Sheep, Swine, &c., in 1872 *and* 1882.

	In the decade	Number
Cattle	Increase	170,798
Sheep and lambs	Increase	314,574
Pigs	Decrease	441
		great hundreds
Eggs	Increase	2,106,558
		cwt.
Wheat, beans, barley, maize, oats, and flour	Increase	26,984,732
		£
Value thereof	Increase	12,197,207

Meat.

	cwt.		£
1881	1,815,327	Value	4,798,915
1882	1,261,235	Value	3,506,290
Decrease in weight	554,092	Decrease in value	1,292,625

In 1870 the import of swine was	95,624
In 1882 " " only	15,670
In 1870 an excess over 1882 of	79,954

The decrease since 1880 of 24,363 horses used in agriculture may be attributed to the thousands of acres untenanted since 1879, and to the change from arable into pasture, such requiring less horse, as also less manual labour.

If 100 acres of arable employs 4 labourers, 1,000 acres, 30 labourers; 10,000 acres, 300 labourers; 100,000 acres, 3,000 labourers; 1,000,000 acres, 30,000 labourers; 1,500,000 will employ 45,000; deducting 15,000, employed in that changed into pasture farming, we have 30,000 less labourers employed thereon than we had on arable farming; taking those wage-earners at 40*l.* per annum each, we have a total of 1,200,000*l.* less paid for manual labour on the same acreage of land, accounting for much that has occurred in our rural districts.

8. *Foot and Mouth Disease of Cattle: its True History and Remedy. By the* Rev. D. Ace, *D.D., F.R.A.S.*

The following is a summary of the points discussed by the author. The disease of foreign origin:—remedy, slaughter foreign animals at the port of debarkation. Losses of animals, waste of food and wealth. Losses both to the producer and to the consumer. Statistics of importations during the past and present year. Action of the House of Commons on Mr. Chaplin's motion. Stringent measures must be used—much more than those heretofore put into execution. The question far more extensive than the agricultural interest, but affecting the supply of food and the aggregated wealth of the community.

SATURDAY, SEPTEMBER 22.

The following Report and Papers were read:—

1. *Report of the Anthropometric Committee.*—See Reports, p. 253.

2. *On the Effect of Alcoholic Drinks on Length of Human Life. By* W. Braham Robinson, *R.N.*

Since the Roman Prætorian prefect Ulpianus wrote on the value of life, facts have been accumulating which admit of the expectation of human life being more correctly estimated than in his day, though much has yet to be learned.

Before the art of printing was discovered, it was of importance, with the view of discoveries in art and science being followed up, that men should live long; and now the true value of long and healthy lives cannot be overrated, even from an economist's point of view.

In this day some insurance societies show that longevity can be increased by simply *not* drinking, as beverages, intoxicating drinks.

There are several mutual life assurance societies which keep the statistics of the lives of the general section and of those persons who abstain from strong drinks quite separate, and some of the facts kindly furnished to the author by these institutions he quotes, bearing in mind that many difficulties at present present themselves in this inquiry which, no doubt, will be eliminated in future years, such as the time the several abstainers insured may have ceased to drink alcoholic liquors, and the quantity and kind they took during the period or periods they were not abstainers.

The most valuable facts are furnished by the United Kingdom Temperance and General Provident Institution, established in 1840, which institution on December 31, 1874, had 9,539 whole life policies in the temperance section and 15,838 in the general.

In seventeen years the following were the results, viz.:—

—	Temperance Section		General Section	
	Expected Claims	Actual Claims	Expected Claims	Actual Claims
1866–70 (5 years)	549	411	1,008	944
1871–75 (5 years)	723	511	1,268	1,330
1876–80 (5 years)	933	651	1,485	1,480
1881–82 (2 years)	439	288	647	585
Total (17 years) . .	2,644	1,861	4,408	4,339

It will be seen from this that the claims in the temperance section are only a little over 70 per cent. of the expectancy, while in the general section they are but slightly below the expectancy.

The Whittington Life Assurance Company keep the statistics of abstainers apart from those who are not abstainers, but their experience is not yet enough to form any exact opinion upon; however, they say 'that teetotalism seems to be favourable to longevity.'

The Sceptre Life Association states that 'during the eighteen years of our history ending December 31 last (1882), we had 116 deaths in our temperance section against 270 expected deaths,' and in this year (letter dated July 23, 1883) the same disproportion prevails, as 'we had 51 deaths, and only 7 of them on the lives of abstainers, whereas to be equal with non-abstainers there should have been 19.'

In the Emperor Life Assurance Office, they have a temperance branch, and they assure lives at a 'less rate than moderate drinkers, thus giving them an immediate advantage of from 3*l.* to 7*l.*, according to age, each 100*l.* assurance.'

In some Accidental offices the assumed superior lives of abstainers is recognised by a charge of 20 per cent. less to teetotalers than to moderate drinkers.

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3. *Forestry.*[1] *By* William Botly.

The author quoted numerous authorities in support of a School of Forestry: the report of the Committee of the House of Commons in 1854; Sir John Lubbock's observations on the vote for Woods and Forests in the last session of Parliament; Mr. Brown's standard work; papers read at the Society of Arts; the Congress at St. Louis in 1872; that at Pesth in 1879; also the Meteorological Congress held at Rome in 1879, which was attended by delegates from different states in Europe, at which the chief question was, 'How can the development of meteorology in connection with agriculture and forestry be forwarded by the congress?' further that, in 1880, there was a conference at Vienna on Agricultural and Forest Meteorology. It was attended by twenty-two representatives, including Austria, France, Germany, Denmark, Hungary, Italy, Belgium, and Switzerland. The questions forwarded by the English Meteorological Society, with remarks, will be found in vol. 17 of the Royal Agricultural Society, occupying twenty pages, by R. H. Scott, M.A., F.R.S., and Secretary of the Meteorological Office. One of the resolutions at Pesth in 1876 recommended 'observations on the influence on climate of the destruction of forests and planting of trees.'

Observing other countries are alive to its importance, therefore, we must not stand still. Scotland is also moving in the right direction, and in our colonies Canada is leading the van. The paper concluded by pointing a few of the obvious advantages to be derived from the planting of trees in our country:—

1. Employment of labour, including nurserymen and tool-makers.
2. Ornamental improvement of landscape, as well as for building and other pur-

[1] Published *in extenso* by the *Southport News*, October 3, the *Irish Farm, Forest, and Garden*, October 13, and other agricultural journals.

poses; nor must we forget the past services of timber in the construction of the wooden walls of old England, and that timber may do so again is the opinion of some of our admirals.

3. Utility in growing timber on land too poor for other culture at a certain profit, though with a distant return.

4. By planting on ridges and slopes of hills, shelter is given to cattle, sheep, and crops, at the same time improving the climate.

5. Those who have not large estates, with hundreds of acres to appropriate to forest culture, may plant belts of Scotch fir interspersed with beech, larch, &c. round their smaller ones with advantage, especially to the east and north, or to the windward of their property.

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4. *On the Introduction of Science into Higher and Middle-class Schools. By* D. Mackintosh, *F.G.S.*

The author remarked that the main object of education was not so much to make better men of business as to make men of business better men. He referred to the improvement which had lately taken place in public schools as regarded the introduction of scientific subjects in addition to chemistry and physics. During his travels in the West of England he had found that principals of private boys' schools had seldom found it practicable to introduce scientific subjects in addition to chemistry, but stated that he had found exceptions in Southport, several towns and villages in Cheshire, in Grove Park, Wrexham, &c. The author had found that in the West of England many ladies' schools, as regarded the teaching of science, had rather deteriorated than improved, and referred to the prominence formerly given in school advertisements to the 'use of the globes.' He had likewise found that, contrary to the general impression, more time was devoted to science in private than in public ladies' schools, though exceptions to this rule in the north-west of England might be found in the Liverpool College for Girls, the Queen's School, Chester, and other places. He had been led to regard the teaching of science in joint-stock companies' high schools for girls as partaking more of show than reality, though to this rule there were exceptions. As regarded the qualifications of teachers, he believed that the mere circumstance of having passed an examination, or of having received a certificate, was of secondary importance, and that to be able to teach science successfully a teacher ought to go through a special process of self-training in the art of teaching; in other words, he ought to be able, without books or notes, by illustrations, to simplify and render attractive what he taught, so as to impart to his pupils a taste for original scientific research. As regarded the selection of subjects, the author believed that chemistry, physics, or other experimental sciences, however important in themselves, were not without defects from an educational point of view, because many pupils after leaving school were unable to continue the study of these subjects through a want of sufficient apparatus, whereas the study of the natural sciences could be successfully pursued after leaving school, during ordinary occupations. The author had found that geology was the most important science as regarded mental training, not only on account of the magnitude and variety of its subjects, but because it appealed more than any other science to the faculty of wonder, and thereby irresistibly led to the exercise of the reasoning powers.

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5. *The Importance of a Creed Census; with Notice of that taken in* 1881 *for the Diocese of Liverpool. By the* Rev. Canon Hume.

The year 1851 was the year for the decennial Government census, and it was the desire of a large number that the schedules should contain a place for recording the religious professions of the people. But there were others who objected to this proposal, mainly on the ground that there were many who worshipped in Nonconformist Chapels on the evening of Sunday, who yet claimed to belong to the

Established Church. In that year therefore a census of *religious worship* was suggested and obtained, but nothing of the kind has been tried since.

In 1861 a very numerous and important deputation waited on Lord Palmerston, who admitted that he thoroughly concurred in the propriety of having a Creed Census, but stated that the Government could not afford to give offence to a large number of their supporters. In 1871 and 1881 the matter seemed to be given up, and no prominent agitation took place on the subject.

But in 1881 the new Diocese of Liverpool was constituted, and a new Bishop was consecrated and set apart for it. It appeared therefore to be an unusually opportune period for making a census according to creed, apart from the Government altogether.

To this proposal all the usual objections were made, as that it was uncalled for, and the Government had not thought it necessary; that it would be a very expensive undertaking; that the people would not reply to our inquiries; that the results would not be authoritative, however honestly procured; and that people would not give credit to the results when they had been obtained. To all this it can now be replied that not one of the objections urged turned out to be true, and that the whole diocese was carefully enumerated, people of all classes and creeds kindly and courteously affording their aid; that the labour was spread over a period of about nine months, and was mainly in the hands of a few trained and trustworthy enumerators. The city was first completed, and as it was found to contain more than one half the population of the diocese, the incumbents in the more distant parts did not press their objections.

The result for the city was as follows:—

			per cent.
Church of England	264,668	=	53
Dissenters and others	88,861	=	17·8
Roman Catholics	140,115	=	28·1
Religion unknown	5,398	=	1·1
Total	499,042	=	100

These were the parochial or resident people only, but the Government census, which included non-residents who merely slept in the city on a particular night, amounted to 53,383 more, of whom a large number were sailors, travellers, tramps, &c.

For the whole diocese the numbers were as follows:—

			per cent.
Church of England	574,795	=	56·7
Dissenters and others	194,314	=	19·2
Roman Catholics	238,015	=	23·5
Religion unknown	6,639	=	·6
Total	1,013,763	=	100

This leaves 71,131 or 6·5 per cent. for the 'floating population,' the Government census amounting to 1,084,884. As the possibility and facility of obtaining such a census has thus been demonstrated in reference to so large a percentage of the gross population, it is to be hoped that in future the benefits of it will be extended to England and Wales, as they are already to Ireland and the colonies.

MONDAY, SEPTEMBER 24.

The following Papers were read:—

1. *The Growth of Barrow-in-Furness, &c.* *By* HYDE CLARKE, *F.S.S.*

This paper was the application of one laid before the Mechanical Section, so as to illustrate various local topics, as the foreshore question, the development of the

natural harbour of Barrow, the extension of the iron manufacture in Furness. The main object, however, was the description of the plans of the author for the reclamation of waste land in connection with railway transit in the estuaries of Morecambe Bay, the Duddon, and the Solway, and the addition thereby made, or to be made, to the productive soil of the country.

2. *On the Increase of National Wealth since the time of the Stuarts.*[1] *By* M. G. MULHALL.

1. The increase of wealth has been more rapid than that of population, as appears from the following *précis*:—

Date	Country	Wealth	Population	Wealth per Inhabit-ant	Economists of Period
		£		£	
1660	England & Wales	250,000,000	5,500,000	45	Petty, King
1703	„	490,000,000	6,280,000	79	Davenant
1774	„	1,100,000,000	8,080,000	136	Young, &c.
1800	Great Britain	1,740,000,000	10,501,000	165	Beeke, Eden
1812	United Kingdom	2,190,000,000	17,927,000	127	Colquhoun
1840	„	4,030,000,000	26,853,000	150	Porter
1860	„	5,560,000,000	29,064,000	191	Various
1882	„	8,720,000,000	35,004,000	249	„

2. Public wealth has quadrupled since the Waterloo epoch, and doubled since the accession of Queen Victoria, viz.:—

—	1812	1840	1860	1882
	£	£	£	£
Lands . . .	1,066,000,000	1,680,000,000	1,840,000,000	1,880,000,000
Cattle, &c. . .	260,000,000	380,000,000	460,000,000	414,000,000
Houses . .	355,000,000	770,000,000	1,164,000,000	2,280,000,000
Railways . .	—	33,000,000	348,000,000	750,000,000
Shipping . .	15,000,000	23,000,000	44,000,000	120,000,000
Merchandise .	50,000,000	70,000,000	190,000,000	350,000,000
Furniture . .	180,000,000	390,000,000	580,000,000	1,140,000,000
Bullion . .	23,000,000	61,000,000	105,000,000	143,000,000
Foreign loans .	105,000,000	230,000,000	420,000,000	1,080,000,000
Sundries . .	136,000,000	393,000,000	409,000,000	563,000,000
Total . .	2,190,000,000	4,030,000,000	5,560,000,000	8,720,000,000

3. The increase of wealth has been real, and very much in excess of prices, the following standards enabling us to compare the purchasing power of money at the dates in question:—

Period	Grain	Cattle	Labour	Average	Shuckburgh's Table
1640–1690	100	100	100	100	100
1701–1765	88	152	123	121	165
1770–1810	132	167	166	155	258
1821–1848	142	218	201	187	—
1880–1883	117	312	285	238	—

[1] Published *in extenso* by Messrs. George Routledge & Sons, London.

Shuckburgh's table was shown by Arthur Young to be grossly exaggerated. One pound under Charles II. was equal to thirty shillings of George III., or forty-seven and a half shillings at present. According to this scale, the nominal and effective wealth of the nation may be measured thus:—

Date	Wealth		
	Nominal	Effective	Effective per Inhabitant
	£	£	£
1660	250,000,000	595,000,000	109
1703	490,000,000	985,000,000	157
1774	1,100,000,000	1,654,000,000	205
1800	1,740,000,000	2,620,000,000	249
1812	2,190,000,000	3,080,000,000	171
1840	4,030,000,000	5,070,000,000	188
1860	5,560,000,000	5,280,000,000	182
1882	8,720,000,000	8,720,000,000	249

Deduction of 5 per cent. from nominal wealth in 1860, because prices of forty-four principal articles show that decline, viz., from 4,400 to 4,191.

4. Diffusion of wealth since 1840 has been four times greater than increase of population, as shown by carriage licences, probate returns, savings banks, &c. Probate returns show 17 per cent. of population were above want in 1840, and 31 per cent. in 1877. Food consumption per head much increased.

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3. *Gold* versus *Goods*. *By* John B. Martin, *F.S.S.*

Starting from the proposition that the term 'appreciation' or 'depreciation' of gold sounds unfamiliar to us, because we are constantly in the habit of speaking of goods in terms of gold, and forgetting that money is merely a commodity of certified quality, and all transactions merely barter, this paper went on to show that gold is constantly varying in value relatively to any given article, and consequently to articles in general. If, as we say, bread is down, but meat is up, and we consume equal value of each, then so far the value of gold would be unchanged. The object of the inquiry is whether on the whole prices have risen or fallen, that is, whether an income of fixed amount will 'go farther' to-day than it did formerly. Of the causes that most directly affect the demand and supply of gold, the fall or rise in prices, are—(1) an increase or falling off of production of gold, the gold-using population remaining the same; (2) an increase or decrease in population, the gold production remaining the same; (3) an adoption of a gold standard, or discontinuance of the use of silver, by countries formerly using one or the other metal only; (4) war or peace, dearth or plenty, free trade or tariffs were minor causes affecting the demand for gold. The effects of these causes are simply a rise or fall in the exchangeable value of gold, but it is far from easy to say whether as a whole the exchangeable value of gold has of recent years permanently varied. Starting under conditions favourable to good and sound trade, the tendency must be for supply to overtake demand, unless the producer can find new markets, or stimulate demand by cheaper production, and consequently lower prices; the same causes are operating on the producer of so-called raw material, of which a very large portion of the cost is the cost of labour in producing it. Mr. Atkinson of Boston estimated that of the whole price of the entire manufactures of Massachusetts, 90 per cent. was to be put down for cost of labour, 5 per cent. for maintenance of capital, and 5 per cent. for profit; any cost in the price of labour or of interest on capital must at once trench seriously on net profit. The rate of interest undoubtedly affected production, but a comparison of the bank-rate with the index-number for a series of years showed that prices could hardly be said to follow the rate of interest. Referring to previous inquiries into the same subject,

and especially to the papers of Mr. Giffen and Mr. Goschen on the fall of prices, it was pointed out that the index-numbers hitherto compiled were liable to criticism as failing to comply with the conditions that (1) they should start on a fair average of prices; (2) that they should include every class of goods, and also of services rendered, rent, &c., which make up the total of our expenditure; (3) that no article should be scheduled twice in different stages of manufacture; and that (4) each article should be rated at a figure proportionate to its consumption. As to the production and consumption of gold, statistics on these points were of all others uncertain and subject to correction, but it appeared tolerably certain that the gold circulation per head in the United Kingdom was larger in 1883 than in 1844, while credit in the shape of bank-balances was enormously larger; in all probability both the public and the banks were in a stronger position now to meet any call on their resources. A true index-number, could it be ascertained, would probably show that the apparent large decrease in prices was subject to considerable modification, and the rise in the value of Consols and other first-rate securities, which Mr. Goschen had shown to be unaffected by any reduction or augmentation of prices, was probably in a great measure due to the increased wealth of the country, which enabled capitalists to take a lower rate of interest for their money, without curtailing their income. Granting the fall in price of many commodities, and assuming the quality to have remained unchanged, on the other hand rents, rates, &c., had notoriously risen, so had salaries and wages of all kinds, and the amount payable, in one way or another, for 'services rendered' entered very largely into the sum-total of our expenditure. The recipients of these higher wages had probably enforced a higher standard of minimum comfort, and were living in better houses, with better drainage, water supply, &c. The compensation for this must be sought in the more efficient returns in labour for wages received, a more numerous and more thriving population, and greater wealth to the community generally. In the words of Mr. Giffen, the only outlet from the situation was the gradual adjustment of prices which must arise from increasing wealth of population of gold-using countries.

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4. *Method of Measuring Changes in the Value of Gold.* *By* J. L. Shadwell.

The common method of measuring changes in the value of money by the prices of commodities is an unsatisfactory one. Instead of being concentrated on the causes which are peculiar to the precious metals, the attention is distracted by the multiplicity of the causes affecting the value of every commodity. Adam Smith's proposal to make labour the measure of value, which has been ignored by later writers, really affords a solution of the problem. Labour, not being a commodity, has no value of its own; but it enables us to measure the value of commodities, since people will give more or less labour to procure an article, according as they think it more or less worth having.

A comparison of the rates of agricultural wages in the different counties of England in 1850 and 1882, shows that they have risen on the average about fifty per cent. This is equivalent to a fall of thirty-three per cent. in the value of gold; for three ounces of gold will only induce people to perform the same amount of labour as two ounces formerly would. The rise of prices during the same period has been insignificant; but this does not prove that gold has not fallen in value, but simply that other things have fallen also. As the constant tendency of industry is to reduce the cost of every product, it is not surprising that a fall of thirty-three per cent. in the value of gold in the course of thirty years should be unaccompanied by any marked rise in prices. Indeed, if a general rise of prices is insisted upon as the only satisfactory proof of a depreciation of gold, the fact of depreciation will never be established.

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5. *The Scottish Poor Law, past and present, tried by results.* *By* E. A. Macknight.

TUESDAY, SEPTEMBER 25.

The following Report and Papers were read:—

1. *Report of the Committee on the workings of proposed revised New Code affecting the teaching of Science in Elementary Schools.*—See Reports, p. 309.

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2. *A System of Science Demonstration in Elementary Schools. By* W. Lant Carpenter, *B.A., B.Sc.*

The subject of this paper is some of the results which have been obtained during the last few years by the system of science demonstrations first conceived and elaborated by the Liverpool School Board, with the advice of Colonel Donelly, R.E., Professor Huxley, and others; but worked out in greater detail, and possibly in some respects more successfully, in Birmingham. The success in both places, however, has been so great, and the commendations of the system by eminent men who have been made aware of it, have been so strong, as to lead to the belief that, were it more widely known, it would be more generally adopted.

The subjects of instruction at present are:—for boys, elementary physics; for girls, domestic economy, including elementary physics, chemistry, and physiology. No child is admitted to the classes who has not passed Standard IV., but in the Birmingham Schools, a well-arranged system of object lessons prepares the minds of the younger children for the higher system. The essence of that system consists (1) in the entire abandonment of text-books of any kind, the teaching being entirely oral. (2) The employment of a specially-appointed expert, as a demonstrator, (with assistants where necessary), who goes round from school to school with apparatus, &c., repeating the same lesson in each till all have been visited. (3) The encouragement of the children to take part in the demonstrations themselves, and to write out notes of the lessons, which are revised by the demonstrator. (4) The establishment of a central laboratory, for practical work by advanced scholars, &c.

As to results, the most important probably is the general quickening of the intellectual life of the school. In Liverpool, in the three years prior to the introduction of the system, the percentage of passes in 'the three R's' averaged 74·4, while in the five years succeeding its introduction, it averaged 87·8, or an increase actually of 13½, and proportionately of 18 per cent. Another advantage is, the attraction of the attention of teachers to science properly taught as a means of education, and to this may be added the discovery of lads of exceptional scientific ability, and the aid thus afforded them. The actual value of the information given and of the diffusion of a taste for science, are too obvious to need more than a mere mention.

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3. *On the Education of Artisans.*[1] *By* G. B. Barron, *M.D.*

The social economics of every country depend upon and are influenced by the kind of training of the people. The character of every community is stamped with the impress of its national education. All methods of education should aim to give moral tone to the young to fit them for the battle of life. No education is effective without the aid of religion. The vast majority of the young do not obtain that in their homes. The present standard of elementary teaching is too high. Education must not stop with the three R's, but must be pushed on by State aid to practical and manual instruction in workshops provided to teach technology in order to bring up our artisans to a level with those of other countries in the art of producing decorative fabrics.

Art classes wherever established are doing a great work in bringing the poorer

[1] Printed *in extenso* in the *Southport Visiter* in the general daily report of the British Association meeting.

classes face to face with knowledge otherwise out of their reach. We must raise our artisans above the crime-laden floor of ignorance and pauperism, and secure, by proper instruction for those who 'toil and spin,' the foremost place in the civilised world as artificers. There is no national economy in ignorance and pauperism.

The statistics prove large sums expended on national schools. We must not stop here. Government must aid by grants those artisans who are unable to pay for advanced technical work, by placing them in national workshops containing all the requirements to teach the industries of the country after passing a certain grade in general education. The State should imitate the Whitworth scholarships, make small grants of money to the poor class of artisans in aid of general elementary as well as practical education, and encourage art and science teaching in every place, and the Queen's prizes in elementry art and science classes must not be withdrawn. The State to establish and supervise evening classes in connection with colleges, mechanics' institutions, and kindred places, for teaching those who are beyond the ordinary age of school life technology and cognate subjects.

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4. *The True Reason why so many Children try to avoid School Attendance. By the* Rev. Canon Hume.

There has been a good deal of discussion of late respecting the causes of non-attendance at school by a large number of the children of the poor. Those most frequently assigned have been two in number, which may be called, (1) the bodily weakness of the young, arising from deficient food or clothing, and from natural delicacy of constitution; (2) the over-exercise of the brain and nervous system from mental labour continued during many hours, to which home lessons are added, and an insufficiency of healthy exercise and agreeable relaxation.

There is no doubt that both these causes exist, and yet it appears to me that they are very unimportant factors in the production of the result which is admitted. The author's decided opinion, based upon a large experience, is that education is not now made at all so interesting as it was before the Government undertook the patronage of it. The fixing of rewards for the three subjects of reading, writing, and arithmetic has led to an unhealthy pressure which has really retarded progress and disgusted the learners.

For example, except in a few of our best schools, there is a constant effort to teach reading, spelling being scarcely at all known, or rather almost utterly unknown; and instead of each pupil analysing and discovering every word for himself, we find the two horrible systems of 'look and go on,' and some intelligent boy or girl shouting out the difficult word. But the intellectual understanding of the piece read is, in a large majority of cases, wholly neglected; so that at the best all that is learned is a bundle of words, and at the worst a blundering and stumbling guess at these words. In numerous instances the illustrative wood engraving could not be explained, and the instances in which the story or lesson could be intelligibly explained amount to a very small percentage. From forty to fifty years ago it was not unusual for two-thirds of the class to be able to repeat a piece from memory, especially if it were in poetry, the judgment having been made subservient to the memory throughout. But now memory is the only faculty appealed to, and that is badly treated, so that the matter of school lessons is forgotten, not in a few years, but in a few months.

Arithmetic is still worse taught. There are thousands of children in England who have been engaged in Addition in Standard I. during a year, and yet who cannot add four figures, or even three, correctly. The simple fact is that they have practised attempting to add daily, but the subject has never been taught to them, or tested for them, and when they reach subtraction they try to add the two lines together, or take the smaller figure from the greater whether it be above or below.

In Church of England schools the Catechism is still worse taught, but on this subject the author does not propose to dwell. He has shown elsewhere that to a learner it is one of the most difficult books in the English language, and it is certainly the worst taught.

For these and similar reasons the charm of intelligence is gone. Education is reduced to a continuous cram to the boy or girl as a sort of human telephone; and voluntary reading or independent inquiry will inevitably decrease instead of increasing. The capability of reading will descend in thousands of cases to the clumsy mastering of a few verses in the New Testament or a sensational paragraph in a newspaper; the power of writing will collapse till the person writing can only sign his or her name; and arithmetic will diminish to the power of adding a column of a few figures.

The remedy for all this is to teach the elementary subjects with a vast deal more care, so that the pupil may advance from step to step with facility and pleasure. There will then be no necessity for taxing the memory to retain what has been acquired, as the very words which have been read will rise spontaneously and pleasurably, and the intellectual enjoyment will add a charm to existence.

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5. *The Education of Pauper Children, industrially and otherwise. By the* Rev. Jas. O. Bevan, *M.A., F.G.S.*

The class of children affected may be gathered from the following table:—

Total number	35,223
Classified thus:—	per cent.
Orphans	25·20
Deserted	20·23
Illegitimate	21·90
Legitimate	32·67
	100·00

There are six methods of maintenance and instruction adopted, viz.:—

1. Within the walls of the workhouse.
2. In district schools.
3. In cottage homes.
4. In industrial homes, whence children are sent to elementary schools.
5. Boarding out.
6. In training ships, &c.

1. Is the worst plan that could be adopted. The children are massed together. They become familiar with pauperism, and the life of paupers, as the normal state of existence; they are brought into occasional close contact with degraded inmates; they become acquainted with life on a scale very different from an ordinary household. They exchange parental love for official supervision.

On the other hand, the cost is low, and many opportunities are presented for industrial training.

2. *District Schools.*—Here the association with chronic and professional pauperism is avoided, and the surroundings are rendered more favourable; but the evils attaching to the association of large numbers of young children under unnatural conditions still remain.

3. *Cottage Homes.*—Here the workhouse school and home are split up, and the parts set down in some pleasant country district. Health, general welfare, industrial training are well attended to. Still there are certain disadvantages.

(*a*) There are still in a single dwelling, thirty to forty children, imperfectly classified, with a certain percentage always changing.

(*b*) There is a difficulty in the way of finding efficient foster-parents.

(*c*) Education is carried on in face of great disadvantages. Children all of one grade, poorest of the poor, stunted in intellect, devoid of emulation, deprived of companionship of higher grades.

(*d*) Ratepayers have thus to maintain children until the age of fifteen or thereabouts.

(*e*) Children become restless. After age of thirteen or fourteen, the life does

not seem to suit them, from its lack of adventure; they make others unsettled; often leave homes by stealth.

(*f*) Excessive cost—15*s*. 7¼*d*. at Banstead per head per week.

4. *Experiment tried by Nottingham Guardians.*—Children lodged apart from workhouse; sent to nearest elementary school. Difficulty obviated with reference to mental instruction, still in force with reference to too close association under mere official care and guidance.

5. *Boarding Out.*—General Order of November 25, 1870, permitting boarding-out beyond limits of union. Six hundred thus provided for; instances of excellence of method; statistics of Northern district; advantages of method; children classified, divided into twos and threes; placed in true homes; receive the nearest approach possible to parental love; have their schooling efficiently provided for; communication with workhouse entirely cut off; economy; training of girls attended to; boys not quite so fortunate.

Suggestions were made for the combination and extension of systems.

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6. *Southport as an Example of Modern Enterprise. By* F. Norfolk.

The author said that the town provided an extraordinary example of rapidity of growth, and brilliantly showed what may be done in a short time. The population of what is now the borough of Southport in 1848 consisted of 623 residents; in 1861 there was a population of 8,940; in 1883 it had grown to 35,065. At the census of 1881 the aggregate population of Southport and Birkdale was 42,454. It would be easy to estimate by well-known rules what the increase had been since that time, and the total could not now be much less than 45,000. He had been supplied by Dr. Vernon with health statistics, which showed that Southport stood pre-eminent as a place of health. Further showing the growth of the town, the author stated that at the incorporation of the borough in 1867 there were 1,369 burgesses, whilst in 1882 that number had increased to 4,891. The rateable value of the borough in 1867 was 26,207*l*., and it had increased to 192,661*l*. in the year 1882. This was exclusive of Hesketh and Scarisbrick wards, which were incorporated in 1878. At that time the rateable value of these two wards was 10,789*l*., whilst last year it had reached 24,722*l*. In September 1882, a religious census, organised by the *Southport Guardian*, showed an attendance at religious worship of 87·8 per cent. of the population, leaving only 12·2 per cent. as non-attendants on that day. It was only fair to add that on the occasion referred to there was no special attraction to draw people to the town, whilst there were other things likely to draw thousands away from Southport. For many of his facts he was much indebted to a handbook recently published by Dr. McNicoll, of Southport. He had a table before him (compiled by Mr. Hyde, a local stockbroker), showing the total amount of capital invested in local Limited Liability Companies which he enumerated, giving the total amount of capital and mortgage debts as amounting to 1,620,230*l*. For a town with a population of 45,000 that was undoubtedly good. The author referred to the handsome buildings which adorned the town, and stated that at the present time there were between 7,600 and 7,700 inhabited houses in Southport and Birkdale.

Section G.—MECHANICAL SCIENCE.

President of the Section—James Brunlees, F.R.S.E., F.G.S., Pres.Inst.C.E.

[For Mr. Brunlees' Address see p. 635.]

THURSDAY, SEPTEMBER 20.

The following Papers were read:—

1. *A Comparison of Morecambe Bay, Barrow-in-Furness, North Lancashire, West Cumberland, &c., in* 1836 *and* 1883. *By* Hyde Clarke.

The writer gave an account of his plans and surveys in 1836 for forming a through line of railway from Lancaster, through Furness and West Cumberland, across the Solway to Dumfries, and thence to Glasgow, by the course now adopted by the Glasgow and South-Western Railway. The chief feature was the passage and embankment of the large estuaries called Morecambe Bay. The history of this undertaking was given, with details of the plans of Messrs. Hyde Clarke, George Stephenson, Hague, Rastrick, &c., and the works carried out by Mr. James Brunlees. The plans of the Warton Land Company were described. The effect of the undertaking in the development of Barrow or Foudrey and the iron manufacture of Furness was illustrated.

2. *On the use of the term Stability in the Literature of Naval Architecture. By* Professor Osborne Reynolds, *F.R.S.*

The term stability is one which has been adopted by mathematicians, with its general meaning unaltered—unrestricted. The mathematical as well as the general meaning of stability, is a state of being able to maintain a particular position against any force tending to overthrow it, or when, on being disturbed and left free, of being able to return to its original position. It is one of those few terms used in a technical as well as a general sense, with the same meaning, and this a meaning about which there can be no question. It would appear that stability is not a nautical term, that is to say, not an old nautical term, but has been introduced into the science of naval architecture with mathematics. In nautical language a ship was said to be stiff or crank, according as it offered great or small resistance to upsetting forces, while, if a ship would turn over without upsetting forces she was called topheavy.

The calling in the aid of mathematics to give definite expression to these various qualities in ships, brought in with it the use of the terms stable and unstable equilibrium.

And hence came the use of the term stability as implying the margin of stable equilibrium. But this was going beyond the mathematical use of the term, for stability, as a quantitative measure, has never received mathematical definition —there being so many causes of stability which must each be measured in a different way. Thus the stability of a large oak tree arises from the strength of the trunk, which will resist a very great force, but which, if sufficient force be brought to bear, will lose its condition of stability before it has bent to a sensible extent—while, on the other hand, there is the stability of a ship, a reed, or a cradle, which, while readily yielding according to the magnitude of the disturbing force will not lose its power of resistance until a certain degree of disturbance is attained.

All these objects may be strictly said to possess stability, but if we use the term stability in a quantitative sense to express these qualities, in the one case it must mean a quantity of force, and in the other a quantity of space or angular disturbance.

This difficulty in the quantitative use of the term stability appears to have been lost sight of by naval architects, who used the term to express both the extent of heel which a ship might safely suffer, and also the upsetting force necessary to cause this heel. This confusion has not passed without remonstrance, but it appears from the report of Sir E. J. Reed on the 'Daphne' disaster, and the discussion to which it has led, that naval architects are using the term stability both in its proper sense, as meaning a tendency on the part of a ship to hold a particular position, and also as meaning a tendency in a ship to change its position in a particular direction. Thus, in laying down the rule which he intends to controvert, Sir E. J. Reed expresses it thus. 'If a ship has initial stability, and has some stability also at very large angles of inclination, say 90°, then it is quite certain she will possess some stability at all intermediate angles.' The strict meaning of such a rule would be that if a ship when slightly disturbed from its vertical position would return to that position, and also if, when slightly disturbed from the position of lying on its beam ends, would return to this (beam ends) position, then when slightly disturbed from a position of any particular angle of heel, it would return to that particular angle of heel. As thus interpreted the rule is obviously absurd; and it is clear from the context that in the two phrases 'initial stability' and stability at 90°, the term stability has been used in two contradictory senses. In the first phrase it clearly has its right meaning, namely that if the ship be somewhat disturbed from the vertical position it will return, but what does it mean in the second phrase—stability at 90°. The only interpretation which will make the rule sense and be consistent with the meaning of stability, is that by stability at 90° is meant that for a disturbance of 90° the ship will still be stable about its vertical position. In this sense the rule is intelligible, and necessarily true, and by no means contradictory to anything urged in the report, but this is not the sense in which it is clear by the context Sir E. J. Reed understands it. He clearly interprets stability at 90° to mean a tendency to return from that position towards (*not to*) the vertical. And this interpretation I wish to point out is inconsistent with the strict meaning of the term stability.

It has been long ago pointed out that in order to express the statical qualities of the stability of a ship in definite language, it was necessary to use two terms, the one to express the greatest angle of disturbance from which she would return to her normal position, and it was proposed to limit the quantitative meaning of the term stability to the measure of this angle, using the term stiffness to express the moment of the upsetting forces necessary to produce any particular angle of disturbance.

The adoption of this system, which is consistent and definitive, would prevent the confusion into which it appears naval architects have fallen. It would then be seen that what are ill called curves of stability would be well called curves of stiffness. The importance of this at once appears on applying these curves to determine the sailing qualities of ships—for, supposing the upsetting force of the wind constant, the true stability of the ship, with a given wind and spread of sail, is determined, not by the stiffness, but by whether the stiffness at the particular angle of heel is less than for greater angles. And thus the stability, in a quantitative sense, i.e. the safe angle of heel under wind pressure is limited, not by the heel at which stiffness vanishes, but by the heel at which it becomes a maximum.

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3. *On the Euphrates Valley Railway.* *By* J. B. Fell.

Two ports as points of departure on the Mediterranean were examined by General Chesney and Sir John Macneil, one being Seleucia, the port of Antioch, and the other Alexandretta, in the Bay of Scanderoon; the latter being considered to be the best, as the least expensive to construct, and from its being in a fine

natural harbour, deep enough and large enough to accommodate the whole of the British fleet. From Alexandretta the railway would be carried over the Bailan pass, the summit of which has an elevation of 2,100 feet, whence the line falls down to Aleppo at a distance of 90 miles. From Aleppo the railway runs with easy gradients and over favourable ground to Bussora or Et Kewit, at either of which places on the Persian Gulf excellent landing accommodation could be provided for the largest ships afloat.

The length of the line from Alexandretta *viâ* Bagdad to Bussora, would be 850 miles, the average gradient 1 in 500, and there would be but few curves beyond Aleppo less than 20 chains' radius.

The estimated cost for a full gauge single line with passing places is 10,000*l.* per mile, or 8,500,000*l.*

Sir William Andrew estimates the through traffic at 406,521*l.* per annum, and the local traffic at 540,681*l.*, total 947,202*l.* Less working expenses 50 per cent. 473,611*l.*; this would give a nett revenue of 473,601*l.* per annum

The estimated nett revenue of 473,601*l.* is sufficient to pay $5\frac{1}{2}$ per cent. on the estimated cost of the railway.

The Euphrates Valley Railway would therefore be able to compete on advantageous terms with the Suez Canal, and it might not be an extravagant estimate to assume that it would carry one million tons of goods or even more per annum, out of the four and a half millions of tons of British goods now passing through the canal.

The maximum carrying capacity of the Euphrates Valley Railway may be estimated at three millions of tons of goods for a single line, and ten millions of tons for a double line of railway, per annum.

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4. *On the Construction and Working of Alpine Railways.* *By* J. B. Fell.

There are three Alpine railways in existence at the present time: the Mont Cenis and St. Gothard Railways, which have been made with long summit tunnels and with ordinary gradients; and the Brenner Railway, that has been made with similar gradients but without a long tunnel. In addition to these the Mont Cenis Summit Railway, constructed and worked upon the centre rail system, with gradients of 1 in 12, curves of 2 chains' radius, and on a gauge 1·10 metre, carried the French and Italian traffic between St. Michel and Susa, for a period of from three to four years, until the completion of the tunnel line in 1871.

The existing Mont Cenis Railway may be taken as the best example of an Alpine railway made upon the great tunnel system. The length of this line is 78 kilometres. The summit level is 1,338 metres above the sea, and the average gradient is 1 in 53, the maximum being 1 in 30. The construction occupied a period of 14 years, and the cost is stated to be 133 millions of francs, being at the rate of 109,729*l.* per mile. The net revenue, based on the official returns of 1880, is 1,020,000 francs after payment of working expenses. The interest on the capital employed is 6,650,000 francs per annum; and, after taking into account the earnings of the railway, there is a deficiency of 5,630,000 francs, or 228,560*l.* per annum chargeable to the Government Guarantees.

The St. Gothard Railway was opened for traffic in June 1882, and the net earnings for the first twelve months of working have been 5,425,248 francs, while the charge for interest on the capital expended, 287 millions of francs, is 14,450,000 francs, leaving a deficiency of 9,024,752 francs, or 360,990*l.* per annum.

The result of the working of the Mont Cenis and St. Gothard Tunnel railways taken together, therefore, shows a loss of 589,550*l.* per annum, representing an amount of 11,791,000*l.* sterling of unproductive capital employed in these two great undertakings.

This enormous loss is borne chiefly by the French, Italian, German, and Swiss Governments, the large expenditure on these two Alpine railways of 422 millions of francs being justified by their important strategical and political advantages, in addition to their local and commercial value.

Separating the commercial value of these railways from that due to national and State purposes, the former being determined by their net earnings of

6,447,240 francs per annum capitalised, the commercial value is found to be 5,160,000*l*., and that due to national and State purposes 11,791,000*l*. sterling.

The important question has now arisen, and has been taken into serious consideration by the Governments and local authorities interested, as to how far it may be possible to make other trans-Alpine railways, some of which are urgently needed, at a cost that would render them financially practicable; and to accomplish this object it has been proposed to effect a reduction of one-half or more of the cost, by carrying these railways over the mountain passes by means of steep gradients and the use of the centre rail system, as it was adopted on the Mont Cenis Railway. There would, however, be this great difference between that line and the new summit railways, that the latter would be made on the ordinary 4 feet 8½ inches gauge, instead of the narrow gauge of 3 feet 7½ inches; the gradients would be 1 in 15, instead of 1 in 12; and the curves 10 chains', in place of 2 chains' radius, so that a through service, without change of carriages or waggons, could be maintained between Italy on the one side, and France, Switzerland, and Germany on the other side of the Alps.

Upon these improved summit railways the same weight and number of trains could be run that are now running on the Mont Cenis Tunnel Railway, and with the protection of avalanche galleries and covered ways the regularity of the service would be maintained at all seasons of the year.

The extra cost of working expenses caused by working over a higher level than that of a tunnel line would, if capitalised and added to the cost of construction, still leave a clear net saving of more than one-half in the cost of construction as compared with the cost of a tunnel railway.

Of the different projects for additional Alpine railways, the two that are considered of the greatest importance, and most likely to be made within a short period, are—first, the Mont Genevre Railway, from Oulx to Briançon, and second, the Great St. Bernard Railway, from Aosta to Martigny. The former is about twenty miles in length, would place Turin in direct communication with the port of Marseilles, and effect a saving of 100 miles in the distance between the north of Italy and the south-western departments of France. The cost of a summit railway with a super-elevation of 444 metres, or 1,456 feet, would be 16,000,000 francs, and the extra working expenses for a traffic of 100,000 passengers and 100,000 tons of goods per annum, capitalised, would be 3,000,000 francs. The total cost would therefore be 19,000,000 francs, as compared with 40,000,000 francs, which is the estimated cost of this railway if made with a tunnel of about half the length of that on the St. Gothard Railway. There would also be a saving of several years in the time required for its construction.

The Great St. Bernard Railway, from Aosta to Martigny, if carried over the summit of the pass would have an elevation of 2,776 metres above the level of the sea, which is about the same height as the Union Pacific Railway in America, and considerably less than that of the Andes. This summit level might, however, be reduced to 2,344 metres by a short tunnel of 2 kilometres in length, and further reduced to 1,998 metres by a tunnel of 4 kilometres in length.

The cost of a summit railway, including the extra working expenses, would be 30,000,000 francs, and with the short tunnels above named 35,000,000 and 40,000,000 francs respectively, for a total length of about 60 kilometres; whereas the estimated cost of a line with ordinary gradients and a tunnel of 6 kilometres in length is 80,000,000 francs, or double the cost of a line made with steep gradients on the centre rail system with a short summit tunnel.

From the foregoing statement of facts it is evident that great tunnel lines cannot be made without the aid of subventions amounting to at least double the commercial value of an Alpine railway; and that, as the railways already made across the Alps have satisfied all strategical and political requirements, the expenditure on future Alpine railways will probably be determined solely by their commercial and local value. If this should be the case, no more Alpine tunnels are likely to be made, and a less expensive method of construction must necessarily be adopted—such as the steep gradient and centre rail system, or this system combined with a short and inexpensive tunnel.

The result of the experiences of the last twenty-five years seems, therefore, to point to the conclusion that the method of constructing Alpine railways with long, non-paying tunnels is a thing of the past. The future belongs to the best system that can be devised for overcoming the difficulties of trans-Alpine railways, rather by adding to the powers of the locomotive engine, and by other mechanical appliances for reducing the cost of traction on steep inclines, which methods are capable of indefinite improvement, than by burying in gigantic tunnels enormous sums of unproductive capital that, when once expended, are irrecoverably lost.[1]

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5. *The Injector Hydrant for Fire Extinction.*[2] *By* J. H. Greathead, *M.Inst.C.E.*

It is calculated that the fire loss in the Metropolis last year exceeded two and a quarter million sterling, equal to eighteen pence in the pound on the present annual rateable value of property, and that of this sum probably at least one million would have been saved by a system of hydrants with adequate water-supply, such as those which have existed for many years in Liverpool, Manchester, and Glasgow.

The water supply of London, however, although satisfactory as to quantity, has not sufficient pressure for hydrant purposes, and from the fact that the supply has to be pumped up from a low level, instead of coming by gravitation from high sources, as in the towns referred to, it is impossible without enormous expenditure to adapt it for hydrants.

Proposals have been made from time to time for improving the supply or for introducing separate supplies for fire-extinction, but these have been objected to on account of the great cost involved or for other reasons.

At present the requisite pressure for jets is given by the pumps of fire-engines. Where, however, efficiency depends upon the power being available on the instant that the occasion for its use is discovered, this mode of supplying it is eminently unsuitable.

Sir William Armstrong's accumulator system of hydraulic power, generally in use at the docks and goods termini, requires no description. In connection with the injector hydrant it has been found to be specially applicable to the production of jets of water for fire-extinction in cases where the ordinary supply has not sufficient pressure for the purpose. Applied to the Metropolis generally in the same way, it would furnish a complete and efficient system of fire-hydrants, without imposing upon the ratepayers any additional burden, and if the hydraulic power were applied to commercial purposes, there would result a considerable gain to them.

The system can be introduced at once, either generally or locally, because it is not dependent on any question of improved water-supply, and would interfere with no rights or interests.

FRIDAY, SEPTEMBER 21.

The President delivered the following Address:—

The British Association for the Advancement of Science admits to its annual gathering women as well as men; and I venture to think it does so wisely. Women now take their place regularly in the ranks of several scientific professions; and though they have not shown any desire to enter that to which I belong, there has recently been an example of their capability in that direction, which is noteworthy. It has been publicly stated that Col. Roebling, the distinguished engineer of the Brooklyn suspension bridge, which is one of the most remarkable works of the age, was

[1] Published *in extenso* by the author in Southport.
[2] Published *in extenso* in *Iron*, October 19, 1883.

assisted during a long illness in carrying out his work by the talent, industry, and energy of his wife, who acquired theoretical and practical knowledge enough to aid in seeing that her husband's design was properly carried out. I think this example is not unworthy of mention here, as honourable to the individual woman, to the energetic nation to which she belongs, and to the better half of the human race.

The previous meetings of the British Association have been held in places possessing very varied characteristics; but in none in which the pursuits of science could be undertaken under more pleasing circumstances than in Southport, with which I have been acquainted for a good many years.

It is customary for the President of each Section to begin the session by giving an introductory address. I propose, with your kind indulgence, to offer some brief remarks, as far as possible free from technical language, on a subject which is familiar to my own mind, and within my own experience, during a period now approaching half a century, that is: The growth of mechanical appliances for the construction and working of railways and docks.

The railway of the present day is in principle what it was at the outset; but it differs in detail from the original railway as much, or more than the skewer which fastened the dresses of the ladies of Elizabeth's time, from the pin of the present day, or the carpets of this era from the rush-strewn floors of that. The progress has been gradual, but not slow. From the opening of the first railway to the present date is only a period of about sixty years, and in that short time Great Britain and Ireland, the continent of Europe, America, North and South, India, Australia, and Africa, have been pretty well supplied with railway lines, more and more perfect in construction, and in a degree more or less suitable to the needs of their populations.

The growth of the railway line from a mere plank of wood or iron plate, to a rail laid on stone or wooden sleepers; from the rail with a flange, to the smooth rail and the flanged wheel, were early and important, but now almost forgotten steps in the progress of the railway system. The substitution of the flanged wheel for the flanged rail was an organic change which has been the forerunner of the great results accomplished in modern travelling by railway. You may easily imagine the condition to which our railways would be reduced if they were constructed on the principle of street tramways; how they would be obstructed by slight impediments, and how difficult the construction of junctions would be rendered, by considering how the speed and convenience of railway travelling would have been retarded if it had not early been discovered that the rail should be lifted clear of the ground, and the guide put upon the wheel instead of the rail.

After the flange had been abolished from the rail, the form of the rail itself took a good while to settle; and even now there is no universal form of rail, though in this country and in our colonies the double-headed rail generally prevails, and on the Continent the flat-footed or Vignoles rail. At the outset the rail was a mere bar of cast iron, with a surface sufficient for the wheels to roll on, and with a rib deep enough to give strength to sustain the load. Cast-iron chairs were used to hold the rail in position; and as, owing to the nature of the material employed, these chairs were frequently injured, the first efforts for the improvement of the rail were directed to dispensing with the chairs. But the forms of rail introduced for this purpose did not effect their object, for practical reasons which it is not necessary here to go into. Mr. Locke introduced the double-headed rail, the ends of which were at first made to rest in the chair; but the effect of this plan was found to be that the rails were speedily worn at the ends, and they had to be replaced. The fish-plate was introduced to remedy this defect. The fish-plate was a great improvement in the permanent way of railways. It consists, as you are aware, of two plates of iron placed on each side in the hollow of the rail immediately under the head, the plates being held together by bolts passing through them and through the rail, the bolts being screwed up tight to the rail at the joint by nuts. The effect is to make the rails as nearly continuous as is practically possible.

About thirty years ago, when the traffic on railways had been very largely developed, the parts of the permanent way which had at first been thought likely

to be the most enduring, the rails themselves, were found to be more rapidly worn away than was expected. Efforts were made to harden the surface of the rails, and a plan was introduced by Mr. Dodds for this purpose. It was extensively used where rails were subject to special wear and tear, at points and crossings. The conversion was easily effected: it cost only about fourteen shillings to a pound a ton, and it was estimated that it doubled the durability of the rails. If they were turned, of course it increased their durability three times.

The plating of rails with a steel surface was probably begun about 1854. It was not till about eight or ten years later that rails were made entirely of steel.

In May 1862, steel rails were laid down experimentally at Chalk Farm Bridge 'side by side with two ordinary iron rails, and after outlasting sixteen faces of the iron rails they were taken out in August 1865, and the one face only which had been exposed during a period of more than three years to the enormous traffic, amounting to something like 9,550,000 engines, trucks, &c., and 95,577,240 tons, although worn to the extent of a little more than a quarter of an inch,' even then appeared capable of enduring a good deal more work. Steel rails, however, were dear at that period, costing about double (12*l.* 10*s.* per ton) as much as iron rails; therefore, although their advantages were manifest, they could not all at once replace iron. In 1866, Mr. Webb, the locomotive engineer of the London and North-Western Railway, said they had in use 3,000 tons of steel-headed rails and about fifty miles of steel rails; and Mr. Harrison, of the North-Eastern, said he had just contracted for 500 tons. Now, owing to improvements in the manufacture of steel rails, they can be produced as easily and as cheaply as iron rails. It was observed in 1876 that if, in order fully to realise the effect of the enduring quality of steel rails, you take a given section of the busiest portion of one of our leading railways, over which upwards of 7,000,000 tons of live and dead weight pass annually, you would find that the life of a steel rail on that portion of the line would be forty-two years if the traffic remained the same. This would reduce the cost of maintaining the permanent way of railways from 210*l.* to 106*l.* per mile. When you consider that such a saving on a system of 500 miles, which at 25,000*l.* a mile costs twelve and a half millions, is 52,000*l.* a year, or about a half per cent. of the cost of the railway, you will see that, besides some increase of dividend to shareholders, no inconsiderable sum may be, and has been, devoted by the railway systems of Great Britain to the comfort of travellers out of the saving effected by the introduction of steel rails.

You are aware that railways are worked by the aid of an elaborate system of signals, by which those in charge of a train are required to be guided in regard to its movements. When railways were first opened they were worked without any fixed signals, unless a candle placed in a station window on the Stockton and Darlington line may be so designated. The candle indicated that the train was to stop for passengers, and no candle implied no stoppage. No practical steps were taken towards the adoption of fixed signals till the opening of the Grand Junction Railway in 1838. The signal then used consisted of a disc fixed to a spindle with a handle to turn it, with a lamp at night to answer the purpose of the disc by day. This was a mere 'danger' and 'safety' signal. In the same year Sir John Hawkshaw designed a disc signal attached to moveable rails for the Manchester and Bolton Railway, which was set in motion by a handle with a balanced weight attached, so that when the switches were open to the siding, the face of the disc was presented; and if the switches were open to the main line, the side of the disc was presented. The Great Western had a ball signal about the same time for a similar object. The semaphore signal was designed by Sir C. Hutton Gregory in 1841, and erected at New Cross, and was the first great step in advance in railway signalling. Distant signals were first employed in 1846 in Scotland on a branch of the Edinburgh and Berwick Railway, and were generally disc signals. Probably the first distant signals of the semaphore type were those of the Great Northern, which were made in 1852. Automatic signals were tried with considerable care on the Brighton line, but were abandoned owing to practical difficulties in their working.

As the number of junctions increased, it became apparent that not only must separate signals be given for different lines, but that some kind of concurrent

action must be secured between signals and switches, to prevent accident. Sir Charles Hutton Gregory, in 1843, at the Bricklayers' Arms Junction, gathered together chains from all the signals into a stirrup frame, and a sort of parallel motion was fixed to the frame between the stirrups, in such a manner that the depression of any stirrup pushed the parallel motion so as to block one or more of the other stirrups, and thus it was impossible to give two signals which conflicted with one another at the same time. The switch levers were fixed on the same platform with the stirrup apparatus, but were not interlocked with it. The switchman, while working the switches with his hands, worked the signals with his feet. But the switches were not interlocked till 1852. At East Retford Junction a simple contrivance was used to effect this purpose, which Mr. Ransome considers the germ of the elaborate apparatus which is now used at most of the great junctions throughout the country, the main principle of all the systems being that locking bars moving in horizontal planes should interlock the levers moving in vertical planes.

You are acquainted with the outside at least of those long glass houses built high above the line, at important junctions where hundreds of trains pass rapidly by day and night, and you may have caught sight on your way of the long rows of levers with which they are filled. It is with these handles that the signalman inside the glass house sets the semaphore in motion, and at the same time opens the points to direct the train on to a particular line, and perhaps simultaneously close or lock the points of a branch line, thereby preventing the possibility of a second train coming on to the line previously occupied. When the lever is once drawn over, a mechanical contrivance called a 'locking bar' prevents the points being moved until the whole of the train has passed. In fact, with the present apparatus for signalling, the number of trains that may be worked on a line of railway with perfect safety is enormous, and may be said to have reduced the element of human fallibility to as low a point as human ingenuity is capable of compassing.

Audible signals are in use only in foggy weather, and the detonating signal, designed by Mr. E. A. Cowper in 1841, continues to be generally employed in this country for that purpose.

The subject of brake power is one to which very great attention has been given, both in this country and abroad; and certainly, next to the condition of the permanent way and the efficiency of the signalling apparatus, perhaps nothing in connection with railways is of greater importance. Many lives and much property are hourly dependent in a greater or less degree on the power and efficient state and immediate action of brakes. It has been found that most of the collisions which have occurred might have been prevented had those in charge of trains possessed the power of stopping them within a few hundred yards. The higher the speed and the heavier the train, the greater the necessity for a powerful and simple brake, capable of being applied throughout the train in the shortest possible time.

While trains travelled at slow speeds and consisted of a small number of comparatively light carriages, the brake on the wheels of the guard's van and the reversing power of the engine were fairly efficient means of retarding the motion, or completely stopping trains within a distance absolutely necessary for the comparatively safe working of railways. But the demands of the public for increased speed, or the increased speed offered as one of the results of competition, and the growing length and weight of trains caused by the rapid augmentation of the number of passengers, outran the power of the brakes to control effectually the movements of the train. Means were sought to add to the control of trains by brakes; first, by using the power of the steam acting directly on the brakes; secondly, by the connection of several of the old brakes, so as to unite them under the control of a single brakesman; and thirdly, by the introduction of brake apparatus connected with the buffers, so as to make the momentum of the train itself available in generating a retarding force, a result which has not been realised in practice. Colonel Yolland reported to the Board of Trade, in 1858, the result of a series of trials with brakes designed on these principles. The application of the brake to the engine was an old device which had been abandoned

on account of the injury it caused to the engine. Mr. McConnell, whose engine brake was tried by Colonel Yolland, appears to have endeavoured to remove this objection to a brake on the engine, by applying blocks to the rail instead of to the wheels of the engine, the block being forced down on the rail by means of an elbow joint. Colonel Yolland found that the amount of retardation caused by this brake was comparatively small, and insufficient to prevent an imminent collision. The second principle, the connection of several brakes united under the control of one driver, was chiefly represented by the invention of Mr. Newall. In this system two or more carriages, or if necessary the whole train, were fitted up with brake blocks, all of which were brought under the control of one guard by means of a longitudinal shaft, which transferred the motion of the guard's wheel to the brakes throughout the whole length of the train. In this way an enormous increase of retarding power was obtained proportioned to the number of wheels, and consequently to the length and weight in the whole train. This principle has been applied in all good brakes since invented, however actuated; and it appears to be the sound principle for the application of the retarding force. Newall's application of it has only been superseded by the transfer of the motive force from the brake van of the guard to the engine, where it is best placed for immediate application, without manual exertion, and under the control of the engine-driver, who is the first to see any obstruction of the line, and can be easily communicated with by the guard or passengers in case of any other cause for the stoppage of the train than that which may be seen from the front. Indeed, the contrary plan which prevailed for so many years, and is not yet entirely abandoned, appears to be as irrational as it would be to take the reins out of the hands of the driver of a coach and to place them in those of the guard behind. In principle it may be taken to be admitted that the engine-driver should control the brake, that it should be applied to every wheel of the train, and that in certain cases the brake should apply itself to the wheels. All recent efforts for the improvement of brakes appear to have been devoted to making the action of the brakes automatic, and to increasing the rapidity with which they can be applied.

I do not intend to enter into the controversy respecting the best system in use for obtaining these results. There are several systems by which they are attained more or less effectively; and whereas trains which 30 years ago weighed on the average 30 tons, with engines of the same weight, running at 35 miles an hour, could scarcely be brought to a stand in a distance of about 800 or 1,000 yards, now trains of twice or three times that weight, and running at a much higher speed, can be brought to absolute rest in 20 or 30 seconds, and within a distance of from 300 to 400 yards.

When railways were first made, the locomotive was a very imperfect machine, which could only travel economically on roads almost level and straight. As there are no level plains of great length in this country, and as reducing the natural surface of the country to a fair level is both tedious and costly, considerable détours were made to avoid steep gradients or their alternative, long tunnels, deep cuttings, and high embankments. In some cases where a very steep gradient could not be avoided, a stationary engine and rope traction were adopted. The great improvements in the locomotive gradually led to the almost entire abandonment of rope traction in this country; and gradients which it would have been impossible for the earlier engines to surmount with a load equal to their own weight, are now ascended with ease with heavy trains at moderate speeds. Abroad, however, great natural difficulties, and a limited capital, were not infrequently concurrent conditions which offered to the engineer troublesome problems for solution. In some districts the locomotive could not do the required work, and other means have had to be resorted to. The plans adopted for overcoming the difficulty presented by the sudden elevation of the surface over which a railway must pass, may be typified by the wire-rope system, as employed by myself on the St. Paulo Railway of Brazil, and by the central rail system of Mr. Fell, first employed on the Mont Cenis Railway, and since on steep inclines in New Zealand.

In the case of the St. Paulo Railway it was necessary to solve the problem of rising a height of more than 2,500 feet in five miles; and as the cost of the construction of the line was strictly limited, this had to be done with due regard to the cost of the remainder of the line, and also to the proportion of cost of working it in the total working expenses. I chose the stationary engine and wire-rope system as the best under the circumstances, and divided the ascent into four inclined planes, each with a gradient of 1 in $9\frac{3}{4}$ feet, and of an average length of about a mile and a quarter. At the top of each there is a bank-head, with an incline of 1 in 75 feet downwards, where the stationary engine is placed. The inclines are worked by what is known in the North of England as 'the tail-end system,' and are thus partially self-acting, waggons being attached to each end of the rope, and being raised and lowered simultaneously. The arrangement of the rails is peculiar. On the lower half of each incline an ordinary single line is laid, and on the upper half, above the passing place, three rails are laid, forming a double road, with a centre rail common to both. Exactly halfway on each incline, the single line of the lower half and the three rails of the upper half, branch out into a double line of way of sufficient length for the trains to pass each other. This arrangement allows of two lines of pulleys, for carrying the ascending and descending part of the rope, to be laid down above the passing place, while on the lower half a single line of pulleys only is required. Each incline has a winding engine of 150 horse-power. The ropes are of steel wire, and four inches in circumference. There are some special contrivances for keeping the rope in place, and for controlling the movements of the train; but I need only refer to the clip brake, which is supplementary to the ordinary brake. The clip brake grips the rails, and in an emergency, by its use, a train can be brought to a standstill in a few yards. Such an emergency has arisen owing to the breaking of the rope hauling a goods train. The application of the clip brake arrested the train in a distance of sixty-six feet, the rope was spliced, and in three hours the traffic was resumed.

The central rail system was designed by Mr. Fell, and first carried out practically in the railway made over Mont Cenis, under my direction, before the opening of the great tunnel. The peculiarity of the system lies in the use of a deep rail laid on its side between the two ordinary rails; the centre rail is gripped by horizontal wheels, put in motion by the locomotive, the adhesion of which to the centre rail gives the locomotive the force necessary to draw up steep inclines, not only its own weight, but a considerable supplementary load. This is probably the most economical mode of working very steep gradients under ordinary circumstances, and it has been found to answer very well wherever it has been efficiently carried out.

In the early days of railways, the only means of tunnelling through hard rocks was by the slow and costly process of the jumper and blasting. A hole was drilled with a steel-pointed implement, and when it was worked to a sufficient depth to receive a charge of gunpowder the explosive was inserted, the hole was closed, and, by means of a slow fuse, the powder was ignited and a portion of rock was brought down. Many forms of machine drills have been invented by which this process was shortened—some actuated by hand, and others by steam, air, or water-power. What is called the 'Diamond Rock Drill' was an improvement on the drill itself; the steel cutting-surface being superseded by coarse diamonds set in a ring of metal. Several of these drills were fixed on a frame, and, being actuated simultaneously, a corresponding number of holes were at once driven in the face of the rock. Besides the increase of speed in driving each hole, many holes being driven simultaneously, great additional speed in forming the tunnel was obtained. This has been exemplified in cutting the Mont Cenis and St. Gothard tunnels in Europe, and the Hoosac tunnel in Massachusetts, where the length of tunnel to be made through hard rock would have rendered the cutting impracticable by hand-labour within reasonable limits of time and expenditure. For cutting tunnels through the softer rocks, such as sandstone and chalk, machines which cut or scrape away the face have been invented and applied with considerable success. Mr. Brunton's machine was employed experimentally for cutting a driftway in chalk for the Channel Tunnel Company in 1870, and it worked freely at the rate of about a yard an hour, excavating a heading of seven feet diameter. A machine of this kind has recently

been sent to Sydney, to make sewers through the sandstone. Colonel Beaumont and Captain English have invented a machine which effects the same object in a somewhat different manner. This machine has been employed in cutting driftways in the chalk at the rate of about a yard an hour, both in France and in England, and is employed under my direction in cutting a seven-foot heading in the red sandstone for the Mersey tunnel, with considerable advantage. These machines bore the heading, and clear away and load the spoil into waggons, at one operation, and they enable the engineer to dispense entirely with the use of explosives. By this means the surrounding stratum remains intact, no more disturbance taking place than would follow the driving of an auger through a deal board. They are moved by any available power according to the situation; in the cases I have mentioned they have been driven by compressed air, which, as well as driving the machine, effects the ventilation of the heading in which the machine works.

In the construction of railways and docks, one of the most expensive and tedious operations is the excavation of the soil. In England, the cutting of numerous canals had trained a large body of men to special fitness for the execution of such work, which they performed with a manual dexterity and amount of muscular power which have made the British navvy a special force in the execution of great public works. Where labour was comparatively scarce and inefficient, as, for instance, in America, efforts were made at an early period to supplement, and, if possible, supersede, such manual labour by mechanical contrivances. In 1845 a mechanical excavator, after an American model, was used on the Eastern Counties Railway with a certain amount of success. This machine delivered as much as 100 cubic yards an hour at a cost which did not exceed fifty shillings a day. In principle, and generally in detail, it is very much the same as the excavator which is commonly known as the 'steam-navvy' at the present day. The machine was locomotive, and had three other kinds of motion—first, thrusting the scoop or shovel into the earth; second, lifting the scoop when filled; and third, turning round on its centre to deposit the earth in the waggons. At that time thirteen of these machines were in use in the United States; but they have not superseded manual labour in making cuttings and embankments there, and they have been little used here until recently, and even now they only compete successfully with bone and muscle under special circumstances. It is found economical to employ the 'steam-navvy' where there is a large quantity of hard and heavy clay or alluvial soil to excavate, and where the machine will not only effect a gross saving per day, but nearly pay for its cost in the course of a single contract. The disadvantages of the machine are that it is costly, very heavy to move, requires special plant to work with it, is not readily saleable when the work is finished, and costs a good deal to keep in repair. On the other hand, it will work night and day without trouble, it renders the contractor independent of a large amount of hand-labour, and it will work readily in soil with which it is extremely difficult for manual labour to deal. It is much to be desired that the human frame should be relieved of the exhausting labour which makes man a mere beast of burden, and leaves him at the end of his work only fit to lie down to sleep off the effects of his toil, and to regain strength to continue the same round of labour on the morrow. The use of small locomotives for tipping the soil for embankments has relieved the workmen of one very laborious, and sometimes dangerous occupation, and, in a corresponding degree, has diminished the cost of construction.

In the construction of a railway or dock, a large amount of pile-driving is frequently necessary, and the manner of sinking piles has been much considered by engineers, for the purpose of obtaining rapidity and economy in executing their works. For some purposes, where piles were formerly used, cylinders are now sunk, and the manner of sinking them and their form and material have been much studied. For fine sands, such as were met with in piling for the Morecambe Bay viaducts, and the promenade pier in this town, I used a disc-pile, lowered into the sand by its own weight, as fast as the sand was removed from under the disc by a jet of water forced through a tube opening at the foot of the pile—a plan which has been applied by others elsewhere, and notably at Calais harbour-works recently, where a considerable saving has been effected by its use in sinking piles for the repair

of the western jetty. At Morecambe Bay force-pumps were used, worked by a 2-horse steam-engine; here, at Southport, advantage was taken of the pressure on the town mains. At Morecambe the cost of sinking was 2*s.* 6*d.* per foot, and at Southport only 4½*d.*; an economy due to the use of the town water. At Southport twelve piles were repeatedly put down in a tide; at Morecambe the average was scarcely two in a tide.

For hard gravel, shale, or soft rock, such as is met with in the Mersey, I adopted a corkscrew form. Abroad, notably in Brazil, where the deposits are mostly alluvial, the ordinary bladed screw pile was used in one case for a bridge of ten spans, in 35 to 40 feet of water, with perfect success. In the Solway Viaduct, more than a mile long, it was originally intended to use the screw pile; but after getting through a depth of about 4 feet of sand, it was found that there was such an exceedingly hard stratum of gravel, bound with stiff clay underneath, that the screws would not enter, and a round pointed pile was substituted. I have used metal piles instead of cylinders, on account of the greater ease and economy with which they are put in place. In the case of the Eau Brink Viaduct, near Lynn, the span was 111 feet, the screw of the pile 3 feet 3 inches diameter, and the pile 18 inches in diameter. Five piles were placed under each girder, and as the metal in these was equal to a cylinder 4 feet 4 inches diameter, three times the bearing surface was obtained with the same weight of metal. The process of screwing is much simpler than that of sinking cylinders by the pneumatic process, and the whole operation is handier and more economical, wherever it can be adopted.

A great revolution in driving timber piles was effected by Mr. Nasmyth, who adopted the principle of his steam hammer to the purpose. The Nasmyth pile-driver was first employed at an extension of the Devonport Docks, where a very large number of piles had to be used. At the first trial it did in four and a half minutes the work which by manual labour could only be done in twelve hours, and was perfectly successful from the first moment of trial. The Nasmyth pile-drivers generally in use weigh about 24 tons; the boiler weighs 76 cwt.; the hammer weighs about 30 cwt., and delivers a blow every second on the head and shoulders of the pile, driving it down in ordinary soil from 5 to 10 feet per minute. A small engine moves the machine on a tramway, and three men manage the whole apparatus.

Iron cylinders for foundations were first used by Mr. Redman, on the Thames, at Gravesend, for the construction of the Terrace Pier in 1842, and they have since been largely employed all over the world. Many improvements have been made in the methods of sinking cylinders since their first introduction, when they were sunk into the yielding soil by pressure from above. The first practical application of compressed air to the sinking of cylinders appears to have been made in 1839, at Châlons, where it occurred to the engineer to cover over the top of the cylinder, and by the pressure of the air to drive out the water, and admit the workmen inside to remove the earth, and gradually to allow the cylinder to sink into its place. Lord Dundonald had previously patented the same system in this country, where it was first applied in constructing Rochester Bridge.

Several mechanical contrivances, more or less perfect in their operation, have been used for removing the soil inside the cylinders, to assist in lowering them into place. Mr. Milroy, Mr. Bradford Leslie, and others, have designed and used these mechanical aids with much success on the Portpatrick railway bridge across Loch Ken, at the Gorai bridge in India, and on the Caledonian Railway viaduct over the Clyde, and elsewhere. By their means considerable speed has been attained in sinking cylinders in difficult circumstances, and where the employment of the atmospheric system would probably have been impracticable or unusually expensive.

Sir William Fairbairn attributes the suggestion of caissons to General Sir Samuel Betham, in 1798; and the ordinary floating caisson, to which the suggestion applied, has been very extensively used. In the construction of the Keyham Docks, Sir William applied a new form of caisson, to obviate difficulties created by the great width of the dock entrance and the depth of the basin, and to save the time lost in pumping out the old form of caisson. The new caisson was designed

by Mr. Scamp, Deputy Director of the Admiralty Works. This caisson had a rectangular section, and consisted of six horizontal divisions or counterparts, of which two at the bottom formed the air chamber intended to float the caisson a few inches above the cill, so that it might be drawn into a recess out of the way of passing vessels. The next compartments were open to each other, and had a sluice valve on each side to admit water as ballast, to retain the structure in equilibrium, and to balance its floating power. The upper or sixth compartment formed a tank, capable of containing 70 tons of water, supplied from the main by a hose pipe, and was used for sinking the caisson into its place.

A few years later (1858) another form of caisson on a new plan was adopted in the formation of the Victoria Docks, London, to act instead of a coffer-dam, which in the circumstances would have been costly, and have caused loss of time in construction. This caisson, which was made of wrought-iron plates, was rectangular in side elevation, the heel-posts being vertical, and shaped like those of gates, so as to fit into a hollow quoin, as into a kind of rebate. Its height was 31 feet, and its breadth 80 feet. Its curvature was not so great as that of the gates, having a rise, or versed sine, of only 8 feet.

Caissons which slide into a cut in the wall of the entrances at right angles with the waterway have also been used successfully. Their chief advantage is that they can be moved in less time than floating caissons.

There has been some controversy as to the relative advantage of caissons and gates for closing the entrance to docks. The former seem to be in favour in the Government docks; and at the Portsmouth Dockyard extension caissons were exclusively employed. Where a road has to be provided for, probably a caisson is not more expensive than a pair of gates and a swing-bridge; but it cannot be so easy or so quick to handle, especially since the introduction of hydraulic machinery for opening and closing dock gates.

One of the most important operations in connection with shipping is the repairing, cleaning, and painting of ships. For this purpose graving docks, from which the water was removed after the vessel had entered, were and continue to be mostly employed. But during the lifting of the tubes of the Britannia Bridge into place with what were then called hydraulic presses, it occurred to Mr. Edwin Clark that similar means might be used to lift a vessel out of the water and place it in a position to be dealt with similarly to a construction on dry land. Floating docks consisting of pontoons which lifted the vessel out of the water have been used in this country, and more extensively in America, for this purpose; and at San Francisco and Philadelphia a dock was constructed of pontoons in sections called 'camels,' any number of which might be used according to the size of the vessel to be docked. Mr. Clark's plan is quite different from these. His hydraulic dock consists of a number of columns arranged in two parallel rows, in which columns are placed the hydraulic lifting power. Between these two rows of columns extends a frame or cradle, over which the ship is drawn in the water. When the ship is in position the hydraulic lifts are set to work, and they raise the cradle first to the bottom of the ship, which, being properly secured, is then lifted with the cradle clear of the water. There is no difficulty whatever in the management of this form of dock, and it has been perfectly successful; its chief recommendation being that any area of shallow water can be made available for docking large vessels, and that it is especially valuable in tideless seas.

Among the many mechanical appliances for saving labour on railways and docks, the machinery for shipping coal is remarkable; the bulk, weight, and low price of coal render every item of saving in transport relatively important. It is commercially important also that the coal in the different stages of transport from the pit to the distant consumer should be broken as little as possible, and a good deal of attention has been given to contrivances to secure these ends. On the Tyne, coals were brought down to the river on the tramways and put into small barges called keels, holding about twenty tons, from which they were shovelled into the colliers through a porthole; or where the collier could be brought to the river bank, the coal was turned through spouts direct from the colliery waggon into the ship. There was no arrangement for meeting the difference of level caused by the

tide. The first coal drop on the Tyne was put up by Mr. Thomson in 1813, and all subsequent drops have followed the same principle, which was the invention of Mr. William Chapman, of Newcastle. The loaded waggon in its descent raises a counterbalance weight, and when the coals are let out of the waggon, the counterbalance weight brings the waggon back to its original position. The machinery is controlled by efficient brakes. At Middlesbrough, from 1830 to 1842, the coal waggons were raised from the railway to the ship's deck, and there emptied; but when the dock was constructed, special means were adopted for shipping coal rapidly and with as little breakage as possible. Ten drops were erected, connected with the railway by ten diverging lines; the loaded truck is run on to a cradle directly over the hatchway of the ship to be loaded, the cradle and truck descend perpendicularly to near the ship's deck, and the contents are discharged by the man who descends with the cradle operating a lever, and a counterbalance brings the cradle and empty waggon to its original position. The movement of the cradle is completely controlled by brakes, and it can be stopped with ease in any position. Each drop can ship about 150 tons an hour, and in 1845 these ten drops shipped over half a million tons of coal. About the same time Mr. Robinson contrived for the Bute Dock, at Cardiff, a mechanical system of staiths or drops to supersede the barrow system, by which coal brought down in canal boats was wheeled along planks into the ships. As the anthracite and steam coal are generally in large blocks, it is difficult to use a shoot, and as the coal is very friable it cannot be dropped from any height. Mr. Robinson conveyed the ten-ton waggons along the staiths, lowered them to the ship on a balanced platform which tilted when on the deck, and the coal was allowed to slide into the hold.

A great variety of hydraulic machinery has been designed by Sir William Armstrong for coal loading, and it is largely employed at Newport Docks and elsewhere. One of the best arrangements is thus described by the inventor:—'The waggon is lifted vertically upon a cradle by the direct thrust of a ram beneath, and then tipped into a shoot large enough to contain an entire waggon-load of coal. This shoot also rises and falls so as to meet the varying height of the deck, the movement being effected by connecting the shoot with the cradle, so as to lift or lower it to the point required, where it is secured by proper fastenings. A pair of doors is fixed across the mouth of the shoot to regulate the flow of the coal, or to stop it entirely. The tipping of the waggon is done by a press mounted on trunnions, which travels with the cradle and raises the back end of the platform, which is hinged in front, to the necessary elevation. For the initiatory process of forming a conical heap in the ship, an hydraulic swing-crane is affixed to the framework of the hoist, by which the coal is in the first instance lowered in an ordinary tub from the mouth of the shoot into the hold, and there delivered at the lowest possible level. All the movements are guided by valves, which are worked by a man who stands on an elevated platform at one side of the hoist. The same arrangement answers equally well for hopper waggons. In every case the waggons are brought up and taken away by means of hydraulic capstans, turn-tables, or traversing machines, according to the circumstances of each locality, and the rate of shipment is only limited by the trimming of coal in the hold, which must necessarily be done by hand labour.'

Many different kinds of labour-saving machinery, for dock and railway work in loading and unloading, have been invented during the last fifty years, and have had a most important influence on the development of railway and steamship transport. Without such machinery it would be impossible that the present enormous commerce of the country could be carried on. If this machinery were suddenly withdrawn or disabled, the great ocean steamships must lie idle in port, and the greater part of the goods trains of the railways must cease to be despatched. Adequately to describe the many kinds of cranes used at railway stations and in docks would occupy far more time than is at my disposal, according to custom, on these occasions. But you are all more or less familiar with them in daily use, for it is impossible to pass along a wharf, or through a dock or important goods station, without being struck with the rapidity and ease with which goods are transferred by them from ship to ship, or from ship to shore, or from the platform

to the truck of a railway train. Much of the work which was done by the steam crane is now done by the hydraulic crane, the first example of which, in a stationary form, was applied by Sir William Armstrong upon Newcastle Quay in 1846, speedily followed by hydraulic cranes and hoists at the Albert Dock, Liverpool. They were first applied to railway purposes at the Newcastle station of what is now the North-Eastern system, in 1848; and Mr. Brunel used hydraulic power three years later not only for cranes, but for the movement of turn-tables, traversers, and capstans for hauling waggons at the Paddington station of the Great Western Railway; and now not only stationary, but portable hydraulic machinery is employed at most of the more important goods depôts throughout the kingdom. Hydraulic machinery has also been largely employed for opening and closing dock gates and suices, and for warping ships through the locks.

A large dock is in course of construction at Hull, by Mr. Abernethy, called the Alexandra Dock, where almost every kind of machinery which can be used in work of that nature is being used by the contractors, Messrs. Lucas and Aird, to expedite the work. Two of Priestman's steam grabs are employed, each capable of filling about 390 cubic yards a day, and are found very useful in opening out work for the steam navvies, six of which are employed, each being capable of filling 600 cubic yards a day. There are a number of steam cranes, steam pile-driving machines, and steam jiggers at work. But beside those moved by steam power, hydraulic power has here for the first time been applied to machinery for the construction of works. An hydraulic crane puts the stonework of the dock walls in place; an hydraulic jigger raises the barrow-loads of soil from the bottom of the dock to the wall where it is shot to the back for filling. One of the six navvies is moved by hydraulic power; and there is an hydraulic pile-driving machine. The hydraulic machinery is found to work at least as quickly, as easily, and as economically as steam machinery, and it works almost without noise and quite without smoke. The trial of hydraulic machinery for these purposes has been quite successful, and where circumstances permit it will no doubt be used extensively in works of construction in future. For dock work much of the hydraulic machinery can be used permanently in the ordinary operations of loading and unloading, so that the loss by sale of such expensive plant, which a contractor has to take into account when making his tender, will be avoided, as it can be turned over to the dock company, with a reasonable deduction for wear and tear, at the end of the work. There are 2,800 men employed at this dock; and the work is carried on at night by the aid of the electric light. The mechanical navvies and grabs do the work of about 400 additional men.

The working of railways by electricity has not advanced further than to justify merely a brief reference to it in this paper as among the possibilities, perhaps the probabilities, of the not distant future. A line of a mile and a half of tramway has been working successfully at Berlin for over two years without hitch or accident of any kind. A line of narrow gauge railway is constructed from Portrush, the terminus of the Belfast and Northern Counties Railway, to Bush Mills, in the Bush Valley, a distance of six miles, which is now partially worked by electricity, and is to be wholly so worked as soon as the necessary plant is completed. As the generating power is that of the abundant streams of the neighbourhood, it will be economical; and if success should crown this practical experiment, it may lead to important results in regard to the employment of electricity under similar circumstances as a locomotive power.

I have now passed rapidly in review some of the more striking mechanical improvements in the construction and working of railways and docks which have taken place chiefly within my own experience. Each of them has had an influence important, if unnoticed, in promoting the growth of our railway and dock systems. Precisely how far any single appliance has contributed to create these magnificent systems, of which this country may with just reason be proud, it would be difficult to say; and it would be as difficult to say which of them could be dispensed with without injury to the rest. They may be laid aside in course of time, one by one, as mechanical ingenuity devises new and better plans to take their place, and to meet the new and larger wants of other generations. But as

the present age looks back with respect and veneration to the creation of those monuments of engineering science of which little more than ruins or even historic records remain, so will the generations which succeed us look on these, our works, as worthy, and as having contributed in no small degree to the greater and more general civilisation to which we hope those who follow us may attain.

The following Report and Papers were read:—

1. *Report of the Committee on Patent Legislation.*—See Reports, p. 316.

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2. *On the Supply of Hydraulic Power.*[1] *By* EDWARD BAYZAUD ELLINGTON, *M.Inst.C.E.*

The object of this paper is to show the advantages of hydraulic transmission of power over large areas, and to give an account of the works already established in London and Hull for the supply of power on this system.

The author does not think any one form of power will meet all demands, but hydraulic transmission is one of the most important means of distribution. At present the great natural sources of power, such as the tides, are not available, and whatever system of supply is adopted has to be produced from the combustion of coal.

The author then discusses the various systems of transmission available.

Compressed air is extravagant, and only suitable where ventilation is needed and in a few special cases. Steam has been tried on an extensive scale in the United States, and has failed there.

Gas is a much more important means of distribution, but gas is fuel laid on, and after being burnt in a gas-engine some further system of transmission is needed to bring the power to the machines. In perhaps the majority of instances hydraulic transmission is the most economical method of utilising the power of a gas-engine, especially for lifting and other intermittent work. Electricity is even less likely than gas to supersede hydraulic power, for electricity must be produced from some other power, and when produced must be ultimately redistributed by some other means. Hydraulic power can, however, be economically used to produce electricity for lighting and other purposes.

Hydraulic pumping engines are the most economical machines for utilising the power obtained from the combustion of coal at present available. Hydraulic power when obtained in this way can be utilised direct for many purposes in a manner analogous to the production of light by the electric current, or by the burning of a gas jet—*e.g.*, in an hydraulic ram lift or press.

When rotary engines are required the best power to use must be determined by local conditions.

Hydraulic power is available for the extinction of fire, either direct or by imparting pressure to the ordinary supply, on the injector system, thus acting as a continuous fire-engine. Hydraulic power is pre-eminently suitable for public supply, because of its economy, the simplicity of the machinery employed, its applicability to the extinction of fires, and the small inconvenience to the public thoroughfare which its supply entails.

The author then gives a description of the works in Hull and London, and some statistics showing the economy of the system. The cost to consumers for lifting is from one halfpenny to three farthings per ton, lifted 50 feet; and whereas 500 lifts or cranes if worked by isolated engines would consume 25,000 tons of coal per annum, they could all be worked from one centre, on the hydraulic system, with 2,500 tons. There is the further saving of labour in the same proportion, and other advantages.

The author advocates the construction of subways in the main thoroughfares of our cities, in order to facilitate the use of the public streets for the many new

[1] Published *in extenso* in *Engineering*, October 26, 1883.

purposes which the modern system of supplying the public wants by combination requires.

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3. *On Compound Locomotive Engines.*[1] *By* Francis W. Webb, *M.Inst.C.E.*

In this paper the author describes his method of compounding the locomotive engine. The system differs from that hitherto adopted, particularly as regards the number and disposition of the cylinders. Instead of having one large and one small cylinder, three cylinders are used, viz. two small high-pressure cylinders, and one large low-pressure cylinder. The two high-pressure cylinders are attached to the outside frame plates immediately under the foot plate, about midway between the leading and middle wheels, and are connected through their piston rods and connecting rods to the trailing wheels. The low-pressure cylinder is placed directly over the leading axle, and its connecting rod lays hold of a single throw crank on the axle of the middle pair of wheels. By this arrangement the engine is practically balanced, and enabled to run steadily at high speeds, and the wheels being driven by separate engines, coupling rods are dispensed with ; it is not even necessary that one pair of wheels should be of the same diameter as the other. A passenger engine constructed on this principle in December 1881, has run more than 100,000 miles, with the heaviest and quickest trains on the London and North Western railway, and the commercial results, when compared with ordinary engines doing the same class of work, have been very satisfactory.

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4. *The Mersey Railway.*
By C. Douglas Fox, *M.Inst.C.E.*—See Reports, p. 370.

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5. *On the Construction and Ventilation of long Railway Tunnels.* *By* T. R. Crampton.

The author explained that by the adoption of three tunnels, they can be constructed cheaper where ordinary locomotives are used, give better ventilation than in one, and that any two of them can be used at pleasure for the traffic, whilst pure air for ventilation passes through the other.

About midway of the length of the tunnels, all of them are connected together by large air-passages (with no valves), so that air may pass freely from one to the other. About midway between the centre of the tunnels and each of their ends is formed a branch at right angles, either above or below the other tunnels, and from this branch openings are formed into each of the tunnels, each opening being provided with doors or valves clear of the main tunnels. The branch is led to any convenient point, at which a pumping engine or exhausting apparatus may be erected for withdrawing foul air from it. If two of the tunnels are left open to this branch, and the third one shut off from it by closing the doors or valves, vitiated air will be drawn off from the two tunnels through the branch, whilst fresh air will enter them, partly through their open ends, and partly at the centre, where it is in communication with the third tunnel, so that fresh air will be drawn along the third tunnel, from the bottom of its vertical shaft, down which air is forced, provision being made for the purpose, and will pass into the other two near their centre, and be drawn through the branch, as above explained ; the quantity of pure air being sufficient, so as to dilute the bad gases.

By means of the doors or valves above mentioned, any of the three tunnels can be used as fresh air inlets, whilst the others are used as outlets for the mixed impure air and gas.

By this means all the three tunnels will be efficiently ventilated, whilst at the same time the line of rails in one tunnel can be repaired, whilst the other tunnels are used for the passage of trains ; and the tunnel in which repairs are going on

[1] Published in the *Engineer*, August 3, 1883, and in *Engineering*, August 10, 1883.

may be made the fresh air inlet tunnel; so that the gangs of men working in it may have perfectly fresh air to work in, and be free from all danger from the running trains. If a breakdown of a train occurs in any one tunnel, that can be at once converted into the fresh-air inlet tunnel, whilst the traffic is carried on through the other two, thereby avoiding delay. It was explained that in the event of motors being invented requiring no ventilation, an additional line of rails would be available for traffic without further delay.

A permanent way was described, by the adoption of which much economy of labour for repairs would result.

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6. *On the Resistance of Beams when strained beyond the Elastic Limit.* *By* WALTER R. BROWNE, *M.A.*, *M.Inst.C.E.*

It is well known that the ordinary theory of the resistance of beams to transverse strain depends on the following assumptions:—

(1) All straight lines normal to the axis of the beam in its unstrained condition remain straight and normal to the axis in its strained condition.

(2) Hooke's law holds; that is, the strain on each layer or fibre is proportional to the stress causing it.

(3) The modulus of elasticity is the same on both sides of the neutral axis; *i.e.* the extension and compression produced by equal stresses are themselves equal.

It is not generally pointed out that the second of these assumptions tacitly involves another, which is as follows:—

(4) The shearing stress acting between the successive layers or fibres may be neglected; in other words, the resistance offered by each fibre to the tensile stress is the same as if it were not connected to the fibres above and below it in any way.

Let M be the bending moment at any given section of a rectangular beam, y the distance of any fibre from the neutral axis, T the unit stress on that fibre, R the radius of curvature; then the above assumptions lead to the equations—

$$T = \frac{E}{R} y$$

$$M = \int T dy \times y = \frac{E}{R} \int y^2 dy$$

Now if the shearing stress between any two fibres is to be neglected, it follows that the shearing strain, or the amount by which one surface has shifted over to the other, must be small. For cases below the elastic limit, in which the original normal sections still continue normal, two successive layers are strained so nearly by the same amount that their difference in length—in other words, the distance by which they have shifted over each other—will be excessively small. Hence, so long as the tensile stress, or T, is within the elastic limit of the material, this condition holds; but when T passes this limit, and especially when it approaches the ultimate tensile strength, the case is different.

We may refer to the actual extension of a bar of mild Siemens steel, as determined by Professor Kennedy ('Proceedings Inst. Mech. Engineers,' 1881, plate 30), under stresses varying from 0 to 60,000 lbs. per square inch. The same figure will represent the actual extension in the successive layers of the extension side of a steel bar of the length and of the depth shown, provided we assume that the stress on these layers increases uniformly from the neutral axis at P to the outside at A, as in the ordinary theory of elasticity it is supposed to do. This assumption, as we have seen, involves the hypothesis that the shearing stress between the different layers may be neglected, and for this it is necessary that the extension of any one layer beyond that next to it should be small. Is this the case? On looking at the figure, we see that the difference in successive extensions is very small up to a point L, where the stress is about 41,000 lbs. per square inch. At this point, however, the extension increases by about $\frac{3}{4}$ inch (in 40 inches), without any further increase of stress; and it then goes on increasing rapidly up to fracture.

Let us consider the behaviour of the fibre at L (taken to be the outside fibre of

the beam), as the bending moment is increased. We may suppose it to extend uniformly, by Hooke's law, till the stress upon it becomes equal to 41,000 lbs. per square inch as shown. If unconnected with the fibres below it would then elongate by about $\frac{3}{4}$ inch. But the shearing resistance of the fibre below will oppose this elongation. In other words, the equation of equilibrium for this fibre, when equilibrium is re-established, will be $T_1 = T + S$, where T_1 is the stress due to the bending moment, T the tensile resistance, S the shearing stress along the line of division between the fibre at L and the fibre next below, say at the 40,000 line. Let us now turn to this second layer, next below. The shearing stress, S, will produce an extension in it, which must be added to the extension due to the external stress, T_1; and when equilibrium is restored, this double stress, $S + T_1$, will be balanced (1) by an increase in the elastic tensile reaction due to this extension in length; (2) by an increased shearing stress, acting between this second fibre and the next below. And the same will hold of the third fibre; that is to say, its length will be increased, producing an increase of the elastic reaction, and at the same time of the shearing stress between it and the fourth layer; and so on down to the neutral axis.

We thus see that the effect of the shearing resistance at L, when the strain approaches the breaking point, will be to increase the elastic tensile resistance T, for every point of the section from L to P, where P is a point at the neutral axis.

But it is the sum of the moments of these successive tensile resistances which balances the external bending moment.

Hence the effect of this shearing resistance will be that an increased proportion of this bending moment will be balanced by the elastic reactions of the material in the parts near the neutral axis, and this will leave a smaller part to be balanced by the elastic reactions of the parts near the outer fibre. In other words, the effect is to throw a greater duty upon the parts of the beam near the neutral axis, and to relieve those at a distance from it, and so to increase the effective strength of the beam.

This investigation seems fully to account for the fact that the transverse strength of a beam is always found to be much greater in practice than when it is calculated by the ordinary theory of elasticity; *i.e.* when the stresses on the different fibres are assumed to be still proportional to their distance from the neutral axis, and the outside fibre is assumed to be strained by its breaking load.

This investigation has also a very important effect on the question of employing solid or open beams, solid or hollow shafts. The ordinary theory of elasticity shows that if we wish to carry the greatest load with a given depth and weight of beam, we should dispose the material in two flanges or ribs, as far apart as possible, and only connected by cross-bracing or a thin web, such as will enable them to work together. All iron and steel girders, &c., are constructed on this theory. Now, in such structures, the maximum load can usually be calculated beforehand with tolerable accuracy, and the girder is always so designed that the greatest stress this load can impose is well below the limit of elasticity. Hence, in such cases the ordinary theory (which is not at all affected by this investigation) may be used with safety. But the case will be quite different for any structure which, by accident or otherwise, is liable to be strained much beyond its limit of elasticity.

For in the same figure suppose the metal from P to L to be absent, and only that beyond L to remain. Then when a stress = 41,000 lbs. per square inch comes on the fibre L, there is no shearing resistance below to take up any part of it: the fibre will extend the full distance accordingly; and the relief to the outer part of the beam, which we have seen to be given by the increased strain thrown upon the inner parts, cannot occur.

This applies especially to shafts, such as the axles of railway vehicles, or the crank shafts of steamers. Both these are liable to be broken, and are not unfrequently broken, by special strains, induced under peculiar circumstances. It has been attempted to render these shafts stronger (for the same weight of metal) by making them hollow. In the case of railway axles the attempt was soon abandoned: but in the case of marine shafts it has been largely carried into effect

since the introduction of steel as a material; and its advantages, so far as stiffness is concerned, have been lately set forth in a paper by Professor Greenhill ('Proceedings Inst. Mech. Engineers,' April 1883). In the discussion on that paper, however, Mr. Edward Reynolds, of Sheffield, quoted some experiments made by him on hollow and solid shafts under the impact test, in which the hollow shaft was much the inferior of the two, and gave way very rapidly when once the strain exceeded a certain limit. This is exactly what the theory now given points out would be the case.

It would seem, therefore, that the provision of hollow shafts is a serious error in all such cases, and should not be continued.

SATURDAY, SEPTEMBER 22.

The Section did not meet.

MONDAY, SEPTEMBER 24.

The following Report and Papers were read:—

1. *Report of the Committee on Screw Gauges.*—See Reports, p. 318.

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2. *On Nest Gearing.*
By Professor FLEEMING JENKIN, *F.R.S.*—See Reports, p. 387.

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3. *On Telegraphic Intercommunication.* *By* W. H. PREECE, *F.R.S.*

The ABC telegraph of Wheatstone was used in 1864 in Newcastle, and an Exchange formed there to facilitate intercommunication among the subscribers. In 1882 the ABC apparatus was replaced by telephone, and a great impetus given to this mode of transacting business. All the outlying manufacturing district was brought into the system. The wires are placed underground, and are used in metallic circuit. The Gower-Bell form of telephone is that used. A special form of switch board has been designed by which prompt attention is secured, by which the switch clerk can see at a glance the condition of every wire, whether it is engaged or not, and whether the subscriber is in his office or not. There are over 330 subscribers. The average number of telegrams dealt with daily is 210, and the number of exchanges of intercommunication 2,200.

The system now embraces Newcastle, Sunderland, South Shields, Tyne Docks, West Hartlepool, and Middlesbrough.

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4. *On Electric Launches.* *By* A. RECKENZAUN.

The paper commenced with a description of the launch 'Electricity,' which made her first trip in September 1882.

The 'Electricity' is 25 feet long, with a 5 feet beam, and draws 21 inches forward and 30 inches aft. Her speed is 8·3 miles per hour with ten passengers on board. Forty-five Sellon-Volckmar accumulators stored under the seats and decks forward and aft supplied the current to two Siemens D_3 Series dynamos placed side by side on the floor of the boat, with their axes parallel to the propeller shaft.

A Carliss-Browne two-bladed propeller, of 20 inches diameter and 3 feet pitch, was employed in these first experiments; straps and pulleys were resorted to in order to reduce the speed of the screw to 350 revolutions, whilst the motors revolved at 950 revolutions per minute.

The two motors were coupled in parallel circuit, whereas the cells formed one series. Each machine had its own switch and ammeter, and the starboard machine could be stopped mechanically by means of a friction clutch on the countershaft. Both machines were tested with a Prony brake, and they gave 1·86 horse-power on the brake at 950 revolutions, consuming a current of 21 ampères and 100 volts. At 694 revolutions, 100 volts and 33·25 ampères, the brake horse-power rose to 2·78.

With forty-seven cells on board, the current used by both motors running together was 46 ampères, and the propeller made 360 revolutions; when disconnecting one of the motors the current passing through the other was 33 ampères, and the speed of the propeller shaft fell to 250.

Messrs. Siemens' dynamos lend themselves very readily to the purposes under consideration; the height of a D_3 machine is only 10 inches, length 28 inches, and width 23 inches. The two machines weigh together 632 lbs., countershaft, supports and pulleys 180 lbs., total for the driving apparatus 812 lbs.

Each Faure-Sellon-Volckmar cell as manufactured by the Electrical Power Storage Company for these launches weighs 56 lbs., and it is capable of furnishing 350 ampère hours, or a fairly constant working current for 7½ hours at full speed of boat.

A cell is made up of forty lead plates, each 7½″ long by 5¼″ wide and barely ⅛″ thick, placed vertically in an ebonite box containing diluted sulphuric acid; covers are provided to prevent spilling of liquid; the external dimensions of each box are 8¾″ long, 8″ wide, and 7½″ high.

In later experiments with the boat the two D_3 dynamos were now replaced by one D_2 Siemens machine, this machine being directly connected to the screw shaft.

The weight of this machine is 658 lbs., the space occupied 15″ in height, 30″ in length, 28″ in width. A new propeller with two blades on the lines of the Carliss-Browne type was constructed and experimented with; its original dimensions were 19⅞″ diameter, 12·9″ pitch, and 103 square inches of expanded blade area. With forty-five cells in circuit on board, the current consumed was 57·2 ampères, and the screw made 630 revolutions; after altering the blades successively, the screw became reduced to 17¾″ diameter, 11½″ pitch, and 66 square inches of expanded blade area; at this point the machine only required 43 ampères of current with 46 cells, the screw and armature making 840 revolutions; the speed of the boat being almost the same as originally with a current of 57·2 ampères.

More recently Messrs. Yarrow and Company, in conjunction with the Electrical Power Storage Company, fitted up another electrical launch, destined for the Vienna Exhibition.

This boat is 40 feet long, with 6 feet beam, and can carry 40 passengers; the whole of the machinery and secondary cells are disposed under deck as ballast.

The motor is a Siemens D_2 machine which develops nearly 7 horse-power, with 80 cells and a current of about 40 ampères. As in the last case, the spindle of the armature is coupled to the propeller shaft. The screw is two-bladed, of thin forged steel, and was designed by Messrs. Yarrow; its diameter is 19 inches, pitch 13 inches. The weight of the motor and batteries combined is 2¼ tons.

During the trial over the measured mile the speed of this boat was over 8 miles per hour, the current used at the time being 41·22 ampères, and the counter E. M. F. 112·5 volts with 60 cells in circuit.

The speed of the boat is varied by a commutator, which throws more or less cells into operation.

Forty ampères is a very economical rate of discharge for these small cells, but where great power is required for a short space of time they can yield as much as 80 ampères, and the same weight of accumulators can furnish double the power, but for less than half the time; in this manner very high speeds could be obtained with but a moderate weight.

5. *On Electric Launches.* *By* J. CLARK.

The launch described is a wooden boat, clinker built, 21 feet long over all by 4 feet 4 inches beam, and drawing 12 inches of water with three or four persons on board. She is fitted with an electric motor coupled direct to the propeller shaft, and her power is derived from two battery boxes 3 feet long by 8 inches wide, and 12 inches high, which can be utilised as seats. The batteries require recharging with chemicals about every four hours of continuous use, one battery driving the boat at three quarters speed, while the other is being recharged. During several trials at Kilcreggan-on-Clyde, a speed of a little over five miles an hour was obtained, the motor running at 600 revolutions per minute. The weight of the boat complete, with batteries charged, is 4 cwt. These electric launches are now being built by Messrs. Gilbert Bogle & Co., of Glasgow, of varying sizes, from 15 feet long and four miles per hour speed, to 30 feet long and seven miles per hour speed.

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6. *On Electric Tramways.*[1] *By* M. HOLROYD SMITH.

The author said he had been led to consider the subject on account of a proposal to introduce tramways in the town of Halifax, which presented unusual difficulties owing to the narrow, tortuous, and steep character of many of the streets. Horse traction he considered out of the question there, steam was doubtful owing to the objection the public had to it, and the cable system was inapplicable in consequence of the enormous outlay it would involve, many of the roadways being of solid rock. He then gave an account of the experiments he has made, and explained the plan which he had finally adopted. This is to lay a rectangular pipe or conduit underground between the rails, and to carry the electric conductors on insulated supports within it. The current is collected by a carriage provided with sliding contact pieces, and running in the conduit, and is conducted to the motor on the car by a bracket projecting through a slot running lengthwise of the top of the conduit, like that which in the cable system permits of the passage of the gripping arm. The motor is connected by gearing with a large and broad driving wheel, which travels on the top of the central conduit.

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7. *Secondary Batteries and the Economical Generation of Steam for Electrical Purposes.* *By* W. W. BEAUMONT *and* C. H. W. BIGGS.

The first part of the paper referred to an investigation carried out during the past two years under the direction of Mr. D. G. Fitzgerald in conjunction with the authors, with the view of remedying the defects in secondary batteries of the Faure-Sellon-Volckmar type. The lead plates of such batteries were found frequently to fail in practice, because under the influence of the current they bend or buckle and two plates touch, when they are worse than useless, or the containing lead is acted upon, and the plugs become loose and drop out or do not touch the lead-holder sufficiently to make a good electric contact. The later experiments were carried out by Messrs. Schiassi and Dornbusch at the School of Electric Engineering. The investigations were (1) in regard to the cathode or reducing pole; and (2) relating to the anode or oxidising pole in charging. In the ordinary form of battery the liberated hydrogen at the cathode soon separated more or less completely the active material from the supporting lead. After a long series of trials the lead support had been satisfactorily replaced by carbon, and the result seemed to give an almost perfect plate. But carbon cannot be so used for the anode, because peroxide of lead reacts upon it, and cannot be formed in its presence. Whilst, therefore, the available material is very much restricted at the anode, much can be done to render the material used less liable to deterioration. Two methods had been followed. One was to coat the lead support with material not acted upon detrimentally by dilute acid or by the electric current,

[1] Published *in extenso* by the author (Halifax).

leaving a comparatively small surface that can be acted upon. It was found that the material known as Prout's glue gave good results. Another device was to use as the support a material electro-negative to lead, so that a comparatively ineffective local couple was formed. Altogether these experiments have now resulted in the ability to construct a secondary battery which may be left for some time without appreciable loss, and the life of which is greatly extended beyond what was hitherto possible. The second part of this paper dealt with the economic generation of steam for electric and other purposes. It described a special combination of elephant boiler with the ordinary furnaces replaced by coke ovens. By these means the gases usually wasted from coke ovens were utilised in the production of steam. The coke produced was of the hard kind required for foundry and smithshop purposes, and its value was equal to or greater than that of the coal from which it is produced. The system had been in use considerably over two years with complete success.

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8. *Fire Risks of Electric Lighting.* *By* KILLINGWORTH HEDGES.

There is a great difference between the electric currents which have been in constant use for telegraphic purposes, and those which are to be supplied by the undertakers under the Electric Lighting Act. The latter can only be said to be free from danger when the heat generated by the current is utilised in its right place, and not developed in the conductors or wires which lead the electricity to the incandescent lamps.

The Fire Risk Committee have already issued rules for guidance of users of electric light; these can hardly be said to embrace all the salient points of the new subject, which can only be arrived at after years of practical work. The necessity of proper regulations has already been recognised by the insurance offices, both in the United States and Germany, and some of their special rules are given in this paper.

The conductors must be properly proportioned for the current they have to carry; whatever resistance there is in the conductor will cause a corresponding development of heat, which will vary with the amount of electricity passing, and inversely as the sectional area.

The material must be free from impurity, otherwise an impure section will increase the resistance. The extraordinary difference in the conducting power of a sample of 'commercial' Rio Tinto copper wire, as compared with the pure metal, was shown in an experiment by Dr. Matthiessen—the conducting power being only 13·6 as against 99·95 for pure copper.

The continued heating of an impure metallic conductor has a certain effect on its electrical resistance. With the sample just mentioned, the conducting power at 100° C. decreased from 13·58 to 13·558 after the wire had been heated for three days. It does not always follow that there will be a decrease in the conducting power, as, with alloys, the opposite effect is produced. A copper-silver alloy showed an increase of ·264, after having been heated to 100° C. for three days, and a tin-copper, an increase of ·13.

As the temperature in Dr. Matthiessen's experiments was not increased over 100° C., the author has made some further experiments—heating the wires by the electric current from a secondary battery, to within a few degrees of their melting-point.

The materials given on the table printed on the next page were tried—the wires and foils having such sectional area, and so arranged that, on the current being increased by twenty per cent., they were immediately fused.

The total length of each experiment was twenty-four hours, during which time the current passing through varied slightly, and the following is a mean of the results:—

Material	Resistance before Heating	Resistance of Leads	Difference after 24 hours
	ohms	ohms	
No. 1. Commercial Tin wire . .	·815	·8	–·003
„ 2. Lead, soft	·835	·8	–·005
„ 3. Copper, soft	·81	·8	No change
„ 4. Pure Tinfoil	·86	·8	No change
„ 5. Tin and Lead alloy . .	·87	·8	–·160
„ 6. Albo alloy, in foil .	·835	·8	No change
„ 7. Aluminium and Tin alloy .	·82	·8	+·0008

The resistances were in all cases taken at the temperature of the air, which averaged 69°.

The sign – shows that the metal decreased in resistance, and + that it increased after continued heating. Nos. 1 and 3, tin and copper, were found to scale when heated.

A change has been noticed where high tension currents have been sent through a pure copper wire for some time—the wire in the armature of a Siemens' machine, which came under the notice of the author, appeared to be brittle, and gave a fracture unlike pure copper.

The necessity of good electrical connections is very great, also special arrangements of switches and contact-breakers which, when left in unskilled hands, are liable to cause dangerous heating or an arc.

Short circuit is the danger which may be caused by badly arranged wires; most likely a conflagration will ensue unless the remedy suggested by the Fire Risk Committee and the Board of Trade is adopted—of having a cut-out or fusible plug in the circuit which gives way when the current is in excess. These should be arranged to melt if the current is more than ten or fifteen per cent. of the working strength, otherwise absolute safety is not arrived at. Ordinary lead or tin wire cannot be used except for very small currents, as on fusing the metal is scattered in a globular form, when it is liable to cause fire. The plan adopted by the author is to take pieces of foil arranged like the leaves of a book; the thinness of the foil causes it to be almost volatilised when melted. The material found to be the most reliable is a special alloy of aluminium, termed Albo metal, which is extremely tough, and can be worked much nearer to its fusing point than tin or lead.

The safety of an electric light installation is only insured by testing, which should be done by a current of higher electro-motive force than it is intended to use.

When the work has been properly supervised no trouble should be experienced, and the electric light may be said to be much safer than gas, as it is free from those accidents which are due to a servant's carelessness, or by leakage of the pipes. Whatever danger there is with electric lighting is entirely localised to the generating station where the dynamos and engines would be under constant supervision.

TUESDAY, SEPTEMBER 25.

The following Papers were read:—

1. *Improved Current Meters and Mode of taking Sub-surface Observations.*[1] *By* Professor H. S. HELE SHAW.

The difficulties in the way of taking current-meter observations on sub-surface velocities in a river channel or tidal estuary are well known, and have led to the

[1] Published *in extenso* in the *Engineer*, October 26, 1883.

abandonment of that method by one or two of the highest authorities and most extensive experimenters. These difficulties fall under two heads:—

1. The construction of a suitable meter and the determination of its constants.
2. The mode of using it to obtain sub-surface velocities.

The meters which are by far the most generally used have a revolving screw or fan, the number of turns of which in a given time affords a measure of the speed of the current. Instruments of this class have been brought to a tolerable state of perfection, and by means of various devices by which electric communication is established between the screw and the observer at the surface very satisfactory results have been attained. The mode of using this kind of meter at comparatively small depths and moderate velocities is to employ a rod of wood or metal, or an iron tube, by which it is held in the required position. Where the channel is deep and the current swift this method requires either elaborate raft or other arrangements, or the assistance of several men. If, as is very often the case, the channel is a tidal and navigable one, and interruptions are frequent, the taking of a series of observations by these means is a toilsome and laborious task. It is under the latter conditions that the author is at present engaged in taking a series of observations, and this paper contains a brief account of certain instruments employed, and the mode of using them.

One object of the experiments was to obtain velocities at one point near the bottom during the whole rise and fall of the tide. To avoid the labour of frequent observations and the continued attendance above the point with a boat, which would have been otherwise necessary, the plan was tried of supporting the meter at the bottom of the channel instead of suspending it from above. This was done by driving an iron bar into the river bed at low water, and screwing the meter to it in its right position, and at such a depth as to avoid all danger to or from passing shipping.

A self-recording meter was necessary, and the one exhibited was employed. The instrument in its original form has been elsewhere described by the author,[1] but the present form has a most important modification in the recording apparatus. Into the water-tight barrel a spindle passes, which is turned once for fifty revolutions of the screw. At every revolution of the spindle a needle is raised which flies back under the action of a spring and punctures a tinfoil sheet, a specimen of which was shown. This sheet is wrapped round a drum, which is turned uniformly by clockwork once in an hour, so that not only can the velocity be determined by the number of dots in a given space, but also the time at which the particular velocity occurred. In order to use the whole surface of the foil, the piece which carries the marking needle and spring moves along by a slow screw, so that the instrument will record continuously for as long as twelve hours. There is yet another point, viz., that in order to record the time when the tide turns another needle is used, which records the motion in the opposite direction, and the marks on the foil slant the opposite way.

The special objection which was found to hold with this arrangement is the fact that weeds and drift moving along near the bottom get entangled in the fan. In this case there is nothing in the record to enable the cause of the consequent alteration to be detected with certainty. Moreover, the bearings of the fan need frequent examination in the muddy waters in which the instrument was employed, and this it was, of course, impossible to secure.

For this reason the author afterwards employed at all depths the method, which has recently been used by Professor Unwin and other observers, of suspending the meter with a weight. A suitable tail causes the meter to take its proper position in the current, and it can be easily hauled up for inspection.

The author was led to conclude that for the above reasons no meter with a revolving screw could be left to work by itself at any rate under these conditions. Also that the method of suspension by a rope is by far the easiest and most rapid mode of experimenting.

There are, however, at least three serious objections inherent in screw current meters:

[1] *Minutes of Proc. Inst. C. E.*, vol. lxix. p. 399.

(1.) The speed of the fan at even moderate velocities is not proportional to the speed of the water.

(2.) It is impossible to maintain the same conditions of friction for more than a very short time of working, especially in impure water.

(3.) They stop altogether at low velocities.

The first involves considerable expenditure of labour if the records of observations at low velocities are to be worth anything at all. In the first place the meter must be carefully rated at a number of different velocities, and this without elaborate appliances is a difficult matter to accomplish. The result of such a rating made by Mr. R. E. Froude, at the Admiralty Experimenting Works, Torquay, is shown by the curve (exhibited on a diagram), by which the second and third objections were made evident as well as the labour involved by the first.

It was with a view of overcoming the foregoing objections that the instrument exhibited was contrived by the author. A description of this was then given, and its advantages were explained, as well as some of the results obtained by it.

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2. *A Flexible Band Dynamometer.*[1] *By* Professor W. C. Unwin, *M.Inst.C.E.*

The ordinary flexible band dynamometer consists of a band passing over a brake pulley with a fixed weight at one end and a spring balance on the other. The difference of the tensions measures the friction, and the product of this and the velocity of the pulley gives the work absorbed. The chief difficulty in using it is that the oscillations of the spring balance make the determination of one of the tensions inexact. By taking the band over an idle pulley and back over the brake-pulley, the tension to be measured by the spring balance is made very much less, and the effect of errors in measuring it has less effect on the determination of the work absorbed.

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3. *Curves of Air Resistance.* *By* Professor Greenhill, *M.A.*

The author presented a series of curves plotted from experiments by Mr. Bashforth and Herr Krupp, of Essen, on the velocities of projectiles. In these curves the abscissæ represented velocities and the ordinates resistances. At low velocities the curve was a parabola, but at the velocity of sound it suddenly stepped up and pursued another parabola at a constant height above the first. At the speed corresponding to efflux into a vacuum the curve rejoined the original parabola, and followed the law that the resistance varies as the square of the velocity. The part of the curve between the two limits also followed the same law with a constant added. In Mr. Bashforth's experiments the velocity varied from 100 to 2,800 feet per second, and the resistance was tabulated in pounds per circular inch. In Krupp's experiments the speeds varied from 140 to 700 metres per second, and the results were given in kilos. per square centimetre. His curve lay below Bashforth's, indicating a lower resistance, due to difference in the shape of the head of the projectile. The lowest velocity of 100 feet per second, or 70 miles per hour, overlapped, the author said, those dealt with in meteorology and engineering, and gave only a pressure of 10 lbs. per square foot. At 2,800 feet per second the pressure was 35½ lbs. per circular inch, or 6,500 lbs. per square foot. These results did not agree with those deduced from wind pressures.

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4. *Southport Sewage.*[2] *By* Isaac Shone.

By the aid of maps, sections, and diagrams, the author explained his semi-pneumatic and semi-hydraulic system of collecting and ejecting sewage-proper within flat town areas, such as obtain in Southport. His system, while it was specially recommended by him for draining low-lying and flat towns on the 'separate system,'

[1] The *Engineer*, October 1883.

[2] Published *in extenso* by the author (Wrexham).

was, he contended, none the less applicable to towns where the 'combined system' of drainage was in operation, and which might, on that account, be preferred to the 'separate system,' because by the employment of his hydraulic sewage-ejectors fixed at the houses and heads of sewers, and by the employment of his pneumatic sewage-ejectors, distributed over the town to be drained, suitable house-drains and public sewers could always be laid at such gradients as would cause the sewage flowing into them to flow through them at 'self-cleansing velocities,' a condition which if invariably insisted upon would result in the practical extinction of offensive and dangerous sewage-gas emanations.

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5. *On the Rosebridge Colliery Deep Mine and the Winding Machinery Employed. By* G. H. DAGLISH, *M.Inst.C.E.*

In briefly giving the history of this colliery the author states that the shaft passed through the Ince, Furnace, Pemberton, and Wigan mines, including ten distinct sections, before striking cannel, which was done in 1862, after two years' working.

Temperatures were taken at intervals during the sinking of the shaft, and they were found to be as follows:—

At a depth of	558	yards,	78°	Fahr.
„	630	„	83°	„
„	671	„	86°	„
„	761	„	90½°	„
„	800	„	93°	„
„	806	„	93½°	„
„	815	„	94°	„

As an instance of the extraordinary work performed by the winding engines, it is mentioned that 1,976 tubs of coal, of 7½ cwt., were raised in a day of ten hours.

In 1868 the shaft was extended down to the Arley mine at a depth of 806 yards, very little water, which was salt, being found at this depth. It was then found necessary to increase the winding drum to a diameter of 24 feet, and the tail ends of the piston rods were cut off, thus saving friction.

The mean speed of the cage in the shaft is 2,590 feet per minute, and the maximum 5,100 feet, or about fifty-eight miles per hour. This is considered the quickest in England, and until recently the mine was the deepest.

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6. *The proposed Jordan Canal. By* TRELAWNEY SAUNDERS, *F.R.G.S.*

WEDNESDAY, SEPTEMBER 26.

The following Papers were read:—

1. *The British Navy. By* Captain BEDFORD PIM, *R.N., F.R.G.S.*

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2. *On a Self-Registering Ship's Compass. By* ROBERT PICKWELL.

The wooden stand, lashed and screwed to the deck, which carries the ordinary bowl, is covered by the binnacle top with glass windows, the stand being of any convenient height. Inside the outer bowl the compass bowl is hung on gimball rings in the usual way, and the compass card is below the glass cover or lid of the inner

bowl, light being supplied at night by a top lamp. The registering apparatus is fitted in the bowl below the card. It consists of a barrel containing clockwork, which causes a second barrel within the first to continuously revolve at a given speed, the outer barrel being fixed and having two slots cut through on its upper surface parallel to the axis. The compass card has also a slot, curved in such a manner that some one part of it is always across one or other of the straight slots in the drum, and as the inner barrel is when in use covered with a sensitised paper, it will be at once understood that in whatever course the ship is being steered a ray of light either from the sun or from the lamp will pass through the small opening made at the intersection of the curved slot in the card with one or other of the straight slots in the drum envelope, and will produce a black mark upon the prepared paper, more or less distant from the centre of the card, which from its position will give an exact indication of the course of the vessel at the time. The revolving motion of the drum gives the duration of time the ship's head is on each course, as well as the time such courses are changed.

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3. *The Working of Slate Quarries.* *By* A. W. Darbishire.

The author gave an account of the modern method of working slate quarries, the conditions necessary for success, the cost, &c.

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4. *The Action of Waves on Sea Beaches.* *By* A. R. Hunt, *M.A., F.G.S.*

The author referred to the difference of opinion that exists as to the relative accumulative and destructive action on beaches of large and small waves; and further, as to the size of shingle that is propelled by waves to the greatest height.

He endeavoured, by a description of a series of observations and experiments, to show that the ordinary oscillating wind-wave or swell is never converted into a wave of translation, and that it is to the assumption that the character of such ordinary waves is so altered on approaching the shore, that much of the uncertainty at present prevailing is due.

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5. *Harbours of Refuge.* *By* Robert Capper, *F.R.G.S.*

The writer showed how the anomalies of the present system of shipping dues, varying as they do at almost every port in the kingdom, tend to divert certain articles of commerce from Great Britain to foreign ports. He instanced the Eastern trade, which at one time centred in London, having been transferred to continental ports; and the Australian wool trade, which properly belonged to England, was now going to Antwerp; while a large American trade had found its way to Havre. There are about 250 harbours in the United Kingdom governed by local authorities, and about 200 creeks and so-called harbours in the hands of individual proprietors, which are largely supported and maintained by charges upon ships and their cargoes. So complicated is the system that it is impossible to obtain reliable information on the subject of dock charges and the financial position of our harbours. He also showed the varying character of pilotage imposts. In order to compete with foreign ports our import charges, especially on raw materials, must be kept low. He instanced the vexatious divisions and ruling divisions of rating in the port of Liverpool, and also pointed out that the reduction by Mr. Gladstone, when Chancellor of the Exchequer, in 1853, of the articles contained in the customs charges from 460 to 48 had worked with advantage, both to the customs authorities and the harbour authorities. He contended that the charges levied on shipping in Great Britain were extravagant, and urged that a uniform toll of 75 per cent. of what was now levied would be sufficient, without going to the public exchequer, to provide and maintain harbours of refuge and to conform to all the parliamentary requirements as to sinking funds and so on. He held that each

port should bear the cost of its own harbour, but if it were necessary to spend public funds at all, it should be in improving existing harbours of refuge rather than upon new ones.

6. *The Panama Canal. By the* Chevalier de Stoess.

Passing over the various efforts which have been made since the days of Cortez and Pizarro—a period of fully four centuries—to discover a feasible route for the construction of a canal or waterway across Central America, the author described, with some details, the various proposals which have from time to time found favour, down to 1871, when an international congress assembled at Paris under the presidency of M. de Lesseps, provided with a concession obtained from the Columbian Government in the previous year; and after an exhaustive inquiry decided upon the construction of a canal from the Gulf of Limon to the Bay of Panama.

The author then proceeded to describe the work as then in progress, with the latest particulars up to September 14, obtained direct from M. de Lesseps.

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[*An asterisk* (*) *signifies that no abstract of the communication is given*]

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CONTENTS:—Proceedings of the Meeting;—John Taylor, on Mineral Veins;—Dr. Lindley, on the Philosophy of Botany;—Dr. Henry, on the Physiology of the Nervous System;—P. Barlow, on the Strength of Materials;—S. H. Christie, on the Magnetism of the Earth;—Rev. J. Challis, on the Analytical Theory of Hydrostatics and Hydrodynamics;—G. Rennie, on Hydraulics as a Branch of Engineering, Part I.;—Rev. G. Peacock, on certain Branches of Analysis.

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CONTENTS:—H. G. Rogers, on the Geology of North America;—Dr. C. Henry, on the Laws of Contagion;—Prof. Clark, on Animal Physiology;—Rev. L. Jenyns, on Zoology;—Rev. J. Challis, on Capillary Attraction;—Prof. Lloyd, on Physical Optics;—G. Rennie, on Hydraulics, Part II.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTH MEETING, at Dublin, 1835, *Published at* 13*s.* 6*d.*

CONTENTS:—Rev. W. Whewell, on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat;—A. Quetelet, Aperçu de l'Etat actuel des Sciences Mathématiques chez les Belges;—Capt. E. Sabine, on the Phenomena of Terrestrial Magnetism.

Together with the Transactions of the Sections, Prof. Sir W. Hamilton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTH MEETING, at Bristol, 1836, *Published at* 12*s.* (Out of Print.)

CONTENTS:—Prof. Daubeny, on the Present State of our Knowledge with respect to Mineral and Thermal Waters;—Major E. Sabine, on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland;—J. Richardson, on North American Zoology;—Rev. J. Challis, on the Mathematical Theory of Fluids;—J. T. Mackay, a Comparative View of the more remarkable Plants which characterize the neighbourhood of Dublin and Edinburgh, and the South-west of Scotland, &c.;—J. T. Mackay, Comparative Geographical Notices of the more remarkable Plants which characterize Scotland and Ireland;—Report of the London Sub-Committee of the Medical Section on the Motions and Sounds of the Heart;—Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart;—Report of the Dublin Committee on the Pathology of the Brain and Nervous System;—J. W. Lubbock, Account of the Recent Discussions of Observations of the Tides;—Rev. B. Powell, on determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media;—Dr. Hodgkin, on the Communication between the Arteries and Absorbents;—Prof. Phillips, Report of Experiments on Subterranean Temperature;—Prof. Hamilton, on the Validity of a Method recently proposed by G. B. Jerrard, for Transforming and Resolving Equations of Elevated Degrees.

Together with the Transactions of the Sections, Prof. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTH MEETING, at Liverpool, 1837, *Published at* 16*s.* 6*d.*

CONTENTS:—Major E. Sabine, on the Variations of the Magnetic Intensity observed at different points of the Earth's Surface;—Rev. W. Taylor, on the various modes of Printing for the Use of the Blind;—J. W. Lubbock, on the Discussions of Observations of the Tides;—Prof. T. Thompson, on the Difference between the Composition of Cast Iron produced by the Cold and Hot Blast;—Rev. T. R. Robinson, on the Determination of the Constant of Nutation by the Greenwich Observations;—R. W. Fox, Experiments on the Electricity of Metallic Veins, and the Temperature of Mines;—Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them;—Dr. G. O. Rees, Report from the Committee for inquiring into the Analysis of the Glands, &c., of the Human Body;—Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart;—Prof. Johnston, on the Present State of our Knowledge in regard to Dimorphous Bodies;—Lieut.-Col. Sykes, on the Statistics of the four Collectorates of Dukhun, under the British Government;—E. Hodgkinson, on the relative

Strength and other Mechanical Properties of Iron obtained from the Hot and Cold Blast;—W. Fairbairn, on the Strength and other Properties of Iron obtained from the Hot and Cold Blast;—Sir J. Robinson and J. S. Russell, Report of the Committee on Waves;—Note by Major Sabine, being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface; —J. Yates, on the Growth of Plants under Glass, and without any free communication with the outward Air, on the Plan of Mr. N. J. Ward, of London.

Together with the Transactions of the Sections, Prof. Traill's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTH MEETING, at Newcastle, 1838, *Published at* 15*s.* (Out of Print.)

CONTENTS:—Rev. W. Whewell, Account of a Level Line, measured from the Bristol Channel to the English Channel, by Mr. Bunt;—Report on the Discussions of Tides, prepared under the direction of the Rev. W. Whewell;—W. S. Harris, Account of the Progress and State of the Meteorological Observations at Plymouth;—Major E. Sabine, on the Magnetic Isoclinal and Isodynamic Lines in the British Islands; —Dr. Lardner, on the Determination of the Mean Numerical Values of Railway Constants;—R. Mallet, First Report upon Experiments upon the Action of Sea and River Water upon Cast and Wrought Iron;—R. Mallet, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances.

Together with the Transactions of the Sections, Mr. Murchison's Address, and Recommendations of the Association and its Committees.

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CONTENTS:—Rev. B. Powell, Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media; Report on the Application of the Sum assigned for Tide Calculations to Rev. W. Whewell, in a letter from T. G. Bunt, Esq.;—H. L. Pattinson, on some Galvanic Experiments to determine the Existence or Non-Existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alton Moor;—Sir D. Brewster, Reports respecting the Two Series of Hourly Meteorological Observations kept in Scotland;—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle;—R. Owen, Report on British Fossil Reptiles; —E. Forbes, Report on the Distribution of the Pulmoniferous Mollusca in the British Isles;—W. S. Harris, Third Report on the Progress of the Hourly Meteorological Register at Plymouth Dockyard.

Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15*s.* (Out of Print.)

CONTENTS:—Rev. B. Powell, Report on the Recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on 'The Motion and Sounds of the Heart,' by the London Committee of the British Association, for 1839–40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron, and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the Two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838, to Nov. 1st, 1839:—W. Thompson, Report on the Fauna of Ireland: Div. *Verte-*

brata;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13*s.* 6*d.*

CONTENTS:—Rev. P. Kelland, on the Present State of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M.D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific co-operation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Committee appointed to superintend the Reduction of Meteorological Observations; —Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles;—Reports on the Determination of the Mean Value of Railway Constants;—Dr. D. Lardner, Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s.* 6*d.*

CONTENTS:—Report of the Committee appointed to conduct the co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Dr. J. Richardson, Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Dr. Lyon Playfair, Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed 'to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;'—Report of a Committee on the Vital Statistics of Large Towns in Scotland;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s.*

CONTENTS :—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel ;—Report of the Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations ;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations ;—Report of the Committee appointed for Experiments on Steam-Engines ;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds ;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland ;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships ;—J. Blake, Report on the Physiological Action of Medicines ;—Report of the Committee on Zoological Nomenclature ;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable ;—Report of the Committee for conducting Experiments with Captive Balloons ;—Prof. Wheatstone, Appendix to the Report ;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs ;—C. W. Peach, on the Habits of the Marine Testacea ;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology ;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations ;—R. Owen, Report on the British Fossil Mammalia, Part II. ;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst ;—W. Thompson, Report on the Fauna of Ireland : Div. *Invertebrata* ;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, the Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS :—W. B. Carpenter, on the Microscopic Structure of Shells ;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca ;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants ;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars ;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada ;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain ;—Earl of Rosse, on the Construction of large Reflecting Telescopes ;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory ;—Report of the Committee for Registering Earthquake Shocks in Scotland ;—Report of a Committee for Experiments on Steam-Engines ;—Report of the Committee to investigate the Varieties of the Human Race ;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds ;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke ;—F. Ronalds, Report concerning the Observatory of the British Association at Kew ;—Sixth Report of the Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations ;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate ;—H. E. Strickland, Report on the Recent Progress and Present State of Ornithology ;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland ;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata ;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843 ;—W. R. Birt, Report on Atmospheric Waves ;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation ;—J. S.

Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, the Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s.*

CONTENTS:—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lieut.-Col. Sabine, on some Points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s.*

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—Dr. J. Percy, Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our Knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and

recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Aryan and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at 9s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn, on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lieut.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15*s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st

of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water, and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—

William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations;—Dr. John P. Bell, Observations on the Character and Measurements of Degradation of the Yorkshire Coast;—First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54;—Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the

Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage, and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena, Part 1;—Dr. T. Wright, on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15s.

Contents:—A. Cayley, Report on the recent progress of Theoretical Dynamics;—Sixteenth and Final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, de quelques Transformations de la Somme $\Sigma_0^t{}^{-a} \frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des facteurs $a\ (a+1)\ (a+2)$ &c.... $(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the Extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—Dr. John P. Hodges, on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Prof. W. A. Miller, on Electro-Chemistry;—John Simpson, Results of Thermometrical Observations made at the *Plover's* Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Prof. James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, the Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20s.

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–1858;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connel and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857-58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' Paper 'On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;'—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15s.

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops;—A. Thomson, of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahagow, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Brakes for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858-59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858-59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren De La Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air:—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Professor H. J. Stephen Smith Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship Performance;—Report of the Proceedings of the Balloon Committee of the British Association

appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15s.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Prof. Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De La Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Prof. G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Prof. Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for

Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders;—Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING at Cambridge, October 1862, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee;—Report on Tidal Observations on the Humber;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal;—Prof. H. Hennessy, on the Vertical Movements of the Atmosphere considered in connection with Storms and Changes of Weather;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations;—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal;—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities;—A. Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics;—Prof. G. G. Stokes, Report on Double Refraction;—Fourth Report of the Committee on Steamship Performance;—G. J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861;—J. Ball, on Thermometric Observations in the Alps;—J. G. Jeffreys, Report of the Committee for Dredging on the North and East Coasts of Scotland;—Report of the Committee on Technical and Scientific Evidence in Courts of Law;—James Glaisher, Account of Eight Balloon Ascents in 1862;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at* £1 5*s.*

CONTENTS:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present

State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Prof. Airy, Report on Steam Boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published at* 18*s.*

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on Deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s.*

CONTENTS:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds;—Report on further Researches in the Lingula-flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;

—A. G. Findlay, on the Bed of the Ocean;—Prof. A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Prof. Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at* £1 4*s*.

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the 'Menevian Group,' and the other Formations at St. David's, Pembrokeshire; —J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth; —Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the Penetration of Ironclad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at* £1 6*s*.

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis, in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Supplement to a Report on the Extinct Didine Birds of the Mascarene Islands;—Report on Observations of Luminous Meteors;—Fourth Report on Dredging among the Shetland Isles;—Preliminary Report on the Crustacea, &c., procured by the Shetland Dredging Committee in 1867;—Report on the Foraminifera obtained in the Shetland Seas;—Second Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at* £1 5*s*.

CONTENTS:—Report of the Lunar Committee —Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance

Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds;—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the Desirability of Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures;—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published at* £1 2*s*.

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Seagoing qualities of Ships; —Report on Steam-boiler Explosions;—Preliminary Report on the Determination of the Gases existing in Solution in Well-waters;—The Pressure of Taxation on Real Property;—On the Chemical Reactions of Light discovered by Prof. Tyndall;—On Fossils obtained at Kiltorkan Quarry, co. Kilkenny;—Report of the Lunar Committee;—Report on the Chemical Nature of Cast Iron;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Report on the Practicability of establishing a 'Close Time' for the Protection of Indigenous Animals;—Experimental Researches on the Mechanical Properties of Steel;—Second Report on British Fossil Corals;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing;—Report on the Rate of Increase of Underground Temperature;—Fifth Report on Kent's Cavern, Devonshire;—Report on the Connexion between Chemical Constitution and Physiological Action;—On Emission, Absorption, and Reflection of Obscure Heat;—Report on Observations of Luminous Meteors;—Report on Uniformity of Weights and Measures; —Report on the Treatment and Utilization of Sewage;—Supplement to Second Report of the Steamship-Performance Committee;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Mineral Veins in Carboniferous Limestone and their Organic Contents;—Notes on the Foraminifera of Mineral Veins and the Adjacent Strata;—Report of the Rainfall Committee;—Interim Report on the Laws of the Flow and Action of Water containing Solid Matter in Suspension;—Interim Report on Agricultural Machinery;—Report on the Physiological Action of Methyl and Allied Series;—On the Influence of Form considered in Relation to the Strength of Railway-axles and other portions of Machinery subjected to Rapid Alterations of Strain;—On the Penetration of Armour-plates with Long Shells of Large Capacity fired obliquely;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at* 18*s*.

CONTENTS:—Report on Steam-boiler Explosions;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland;—Report on the Sedimentary Deposits of the River Onny;—Report on the Chemical Nature of Cast Iron;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals;—Report on Standards of Electrical Resistance;—Sixth Report on Kent's Cavern;—Third Report on Underground Temperature;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on the Stability, Propulsion, and Seagoing Qualities of

Ships;—Report on Earthquakes in Scotland;—Report on the Treatment and Utilization of Sewage;—Report on Observations of Luminous Meteors, 1869-70;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On a new Steam-power Meter;—Report on the Action of the Methyl and Allied Series;—Report of the Rainfall Committee;—Report on the Heat generated in the Blood in the Process of Arterialization;—Report on the best means of providing for Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s*.

CONTENTS:—Seventh Report on Kent's Cavern;—Fourth Report on Underground Temperature;—Report on Observations of Luminous Meteors, 1870–71;—Fifth Report on the Structure and Classification of the Fossil Crustacea;—Report of the Committee appointed for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison;—Report of the Committee appointed for the purpose of Superintending the Publication of Abstracts of Chemical Papers;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Second Provisional Report on the Thermal Conductivity of Metals;—Report on the Rainfall of the British Isles;—Third Report on the British Fossil Corals;—Report on the Heat generated in the Blood during the Process of Arterialization;—Report of the Committee appointed to consider the subject of Physiological Experimentation;—Report on the Physiological Action of Organic Chemical Compounds;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on Steam-Boiler Explosions;—Report on the Treatment and Utilization of Sewage;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals;—Report on Earthquakes in Scotland;—Report on the best means of providing for a Uniformity of Weights and Measures;—Report on Tidal Observations.

Together with the Transactions of the Sections, Sir William Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s*.

CONTENTS:—Report on the Gaussian Constants for the Year 1829;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—Eighth Report on Kent's Cavern;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Fourth Report on the Fauna of South Devon;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers;—Third Report on Steam-Boiler Explosions;—Report on Observations of Luminous Meteors, 1871–72;—Experiments on the Surface-friction experienced by a Plane moving through Water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer;—Fourth Report on the Treatment and Utilization of Sewage;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships and Currents;—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the Discovery of Fossils in certain remote parts of the North-western Highlands;—Report of the Committee on Earthquakes in

Scotland;—Fourth Report on Carboniferous-Limestone Corals;—Report of the Committee to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Report on the Mollusca of Europe;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report on the practicability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Sixth Report on the Structure and Classification of Fossil Crustacea;—Report of the Committee appointed to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871;—Preliminary Report of a Committee on Terato-embryological Inquiries;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On the Brighton Waterworks;—On Amsler's Planimeter.

Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873, *Published at* £1 5*s.*

CONTENTS:—Report of the Committee on Mathematical Tables;—Observations on the Application of Machinery to the Cutting of Coal in Mines;—Concluding Report on the Maltese Fossil Elephants;—Report of the Committee for ascertaining the Existence in different parts of the United Kingdom of any Erratic Blocks or Boulders;—Fourth Report on Earthquakes in Scotland;—Ninth Report on Kent's Cavern;—On the Flint and Chert Implements found in Kent's Cavern;—Report of the Committee for Investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report of Inquiry into the Method of making Gold-assays;—Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units;—Report of the Committee on the Labyrinthodonts of the Coal-measures;—Report of the Committee appointed to construct and print Catalogues of Spectral Rays;—Report of the Committee appointed to explore the Settle Caves;—Sixth Report on Underground Temperature;—Report on the Rainfall of the British Isles;—Seventh Report on Researches in Fossil Crustacea;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on the desirability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Report on Luminous Meteors;—On the Visibility of the Dark Side of Venus;—Report of the Committee for the Foundation of Zoological Stations in different parts of the World;—Second Report of the Committee for collecting Fossils from North-western Scotland;—Fifth Report on the Treatment and Utilization of Sewage;—Report of the Committee on Monthly Reports of the Progress of Chemistry;—On the Bradford Waterworks;—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships, &c.;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light evolved by Fluid or Solid Substances;—On a periodicity of Cyclones and Rainfall in connexion with Sun-spot Periodicity;—Fifth Report on the Structure of Carboniferous-Limestone Corals;—Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c.;—Preliminary Note from the Committee on the Influence of Forests on the Rainfall;—Report of the Sub-Wealden Exploration Committee;—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore;—Report on Science Lectures and Organization;—Second Report on Science Lectures and Organization.

Together with the Transactions of the Sections, Prof. A. W. Williamson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at* £1 5*s.*

CONTENTS:—Tenth Report on Kent's Cavern;—Report for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Second Report of the Sub-Wealden Exploration Committee;—On the Recent Progress and Present

State of Systematic Botany;—Report of the Committee for investigating the Nature of Intestinal Secretion;—Report of the Committee on the Teaching of Physics in Schools;—Preliminary Report for investigating Isomeric Cresols and their Derivatives;—Third Report of the Committee for collecting Fossils from localities in North-western Scotland;—Report on the Rainfall of the British Isles;—On the Belfast Harbour;—Report of Inquiry into the Method of making Gold-assays;—Report of a Committee on Experiments to determine the Thermal Conductivities of certain Rocks;—Second Report on the Exploration of the Settle Caves;—On the Industrial uses of the Upper Bann River;—Report of the Committee on the Structure and Classification of the Labyrinthodonts;—Second Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Sixth Report on the Treatment and Utilization of Sewage;—Report on the Anthropological Notes and Queries for the use of Travellers;—On Cyclone and Rainfall Periodicities;—Fifth Report on Earthquakes in Scotland;—Report of the Committee appointed to prepare and print Tables of Wave-numbers;—Report of the Committee for testing the new Pyrometer of Mr. Siemens;—Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface, &c.;—Second Report for the Selection and Nomenclature of Dynamical and Electrical Units;—On Instruments for measuring the Speed of Ships;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists;—Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire;—Report on Luminous Meteors;—Report on the best means of providing for a Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. John Tyndall's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIFTH MEETING, at Bristol, August 1875, *Published at* £1 5*s*.

CONTENTS:—Eleventh Report on Kent's Cavern;—Seventh Report on Underground Temperature;—Report on the Zoological Station at Naples;—Report of a Committee appointed to inquire into the Methods employed in the Estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea;—Second Report on the Thermal Conductivities of certain Rocks;—Preliminary Report of the Committee for extending the Observations on the Specific Volumes of Liquids;—Sixth Report on Earthquakes in Scotland;—Seventh Report on the Treatment and Utilization of Sewage;—Report of the Committee for furthering the Palestine Explorations;—Third Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Report of the Rainfall Committee;—Report of the Committee for investigating Isomeric Cresols and their Derivatives;—Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—On the Steering of Screw-Steamers;—Second Report of the Committee on Combinations of Capital and Labour;—Report on the Method of making Gold-assays;—Eighth Report on Underground Temperature;—Tides in the River Mersey;—Sixth Report of the Committee on the Structure of Carboniferous Corals;—Report of the Committee appointed to explore the Settle Caves;—On the River Avon (Bristol), its Drainage-Area, &c.;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee appointed to superintend the Publication of the Monthly Reports of the Progress of Chemistry;—Report on Dredging off the Coasts of Durham and North Yorkshire in 1874;—Report on Luminous Meteors;—On the Analytical Forms called Trees;—Report of the Committee on Mathematical Tables;—Report of the Committee on Mathematical Notation and Printing;—Second Report of the Committee for investigating Intestinal Secretion;—Third Report of the Sub-Wealden Exploration Committee.

Together with the Transactions of the Sections, Sir John Hawkshaw's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SIXTH MEETING, at Glasgow, September 1876, *Published at* £1 5*s.*

CONTENTS:—Twelfth Report on Kent's Cavern;—Report on Improving the Methods of Instruction in Elementary Geometry;—Results of a Comparison of the British-Association Units of Electrical Resistance;—Third Report on the Thermal Conductivities of certain Rocks;—Report of the Committee on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation;—Report of the Committee for testing experimentally Ohm's Law;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee on the Effect of Propellers on the Steering of Vessels;—On the Investigation of the Steering Qualities of Ships;—Seventh Report on Earthquakes in Scotland;—Report on the present state of our Knowledge of the Crustacea;—Second Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fourth Report of the Committee on the Erratic Blocks of England and Wales, &c.;—Fourth Report of the Committee on the Exploration of the Settle Caves (Victoria Cave);—Report on Observations of Luminous Meteors, 1875–76;—Report on the Rainfall of the British Isles, 1875–76;—Ninth Report on Underground Temperature;—Nitrous Oxide in the Gaseous and Liquid States;—Eighth Report on the Treatment and Utilization of Sewage;—Improved Investigations on the Flow of Water through Orifices, with Objections to the modes of treatment commonly adopted;—Report of the Anthropometric Committee;—On Cyclone and Rainfall Periodicities in connexion with the Sun-spot Periodicity;—Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee on Tidal Observations;—Third Report of the Committee on the Conditions of Intestinal Secretion and Movement;—Report of the Committee for collecting and suggesting subjects for Chemical Research.

Together with the Transactions of the Sections, Dr. T. Andrews's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SEVENTH MEETING, at Plymouth, August 1877, *Published at* £1 4*s.*

CONTENTS:—Thirteenth Report on Kent's Cavern;—Second and Third Reports on the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea (Part III.);—Third Report on the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fifth Report on the Erratic Blocks of England, Wales, and Ireland;—Fourth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Luminous Meteors, 1876–77;—Tenth Report on Underground Temperature;—Report on the Effect of Propellers on the Steering of Vessels;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on some Double Compounds of Nickel and Cobalt;—Fifth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Datum Level of the Ordnance Survey of Great Britain;—Report on the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals.

Together with the Transactions of the Sections, Prof. Allen Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-EIGHTH MEETING, at Dublin, August 1878, *Published at* £1 4*s.*

CONTENTS:—Catalogue of the Oscillation-Frequencies of Solar Rays;—Report on Mr. Babbage's Analytical Machine;—Third Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee for arranging for the taking of certain Observations in India, and Observations on Atmospheric Electricity at Madeira;—Report on the commencement of Secular Experiments upon

the Elasticity of Wires;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine;—Report on the best means for the Development of Light from Coal-Gas;—Fourteenth Report on Kent's Cavern;—Report on the Fossils in the North-west Highlands of Scotland;—Fifth Report on the Thermal Conductivities of certain Rocks;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on Patent Legislation;—Report on the Use of Steel for Structural Purposes;—Report on the Geographical Distribution of the Chiroptera;—Recent Improvements in the Port of Dublin;—Report on Mathematical Tables;—Eleventh Report on Underground Temperature;—Report on the Exploration of the Fermanagh Caves;—Sixth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on the present state of our Knowledge of the Crustacea (Part IV.);—Report on two Caves in the neighbourhood of Tenby;—Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Second Report on the Datum-level of the Ordnance Survey of Great Britain;—Report on instruments for measuring the Speed of Ships;—Report of Investigations into a Common Measure of Value in Direct Taxation;—Report on Sunspots and Rainfall; —Report on Observations of Luminous Meteors;—Sixth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Kentish Boring Exploration;—Fourth Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations, with an Appendix on the Filtration of Water through Triassic Sandstone;—Report on the Effect of Propellers on the Steering of Vessels.

Together with the Transactions of the Sections, Mr. Spottiswoode's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-NINTH MEETING, at Sheffield, August 1879, *Published at £1 4s.*

CONTENTS:—Report on the commencement of Secular Experiments upon the Elasticity of Wires;—Fourth Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee for endeavouring to procure reports on the Progress of the Chief Branches of Mathematics and Physics;—Twelfth Report on Underground Temperature;—Report on Mathematical Tables;—Sixth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Atmospheric Electricity at Madeira;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on the Calculation of Sun-Heat Coefficients;—Second Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Report on Observations of Luminous Meteors;—Report on the question of Improvements in Astronomical Clocks;—Report of the Committee for improving an Instrument for detecting the presence of Fire-damp in Mines;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Beeberine;—Seventh Report on the Erratic Blocks of England, Wales, and Ireland;—Fifteenth Report on Kent's Cavern;—Report on certain Caves in Borneo;—Fifth Report on the Circulation of Underground Waters in the Jurassic, Red Sandstone, and Permian Formations of England;—Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland;—Report on the possibility of Establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on the Marine Zoology of Devon and Cornwall;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on Excavations at Portstewart and elsewhere in the North of Ireland;—Report of the Anthropometric Committee;—Report on the Investigation of the Natural History of Socotra;—Report on Instruments for measuring the Speed of Ships;—Third Report on the Datum-level of the Ordnance Survey of Great Britain;—Second Report on Patent Legislation;—On Self-acting Intermittent Siphons and the conditions which determine the commencement of their Action;—On some further Evidence as to the Range of the Palæozoic Rocks beneath the South-east of England;—Hydrography, Past and Present.

Together with the Transactions of the Sections, Prof. Allman's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTIETH MEETING, at Swansea, August and September 1880, *Published at* £1 4*s*.

CONTENTS :—Report on the Measurement of the Lunar Disturbance of Gravity;—Thirteenth Report on Underground Temperature;—Report of the Committee for devising and constructing an improved form of High Insulation Key for Electrometer Work;—Report on Mathematical Tables;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on Observations of Luminous Meteors;—Report on the question of Improvements in Astronomical Clocks;—Report on the commencement of Secular Experiments on the Elasticity of Wires;—Sixteenth and concluding Report on Kent's Cavern;—Report on the mode of reproduction of certain species of Ichthyosaurus from the Lias of England and Würtemburg;—Report on the Carboniferous Polyzoa;—Report on the 'Geological Record';—Sixth Report on the Circulation of the Underground Waters in the Permian, New Red Sandstone, and Jurassic Formations of England, and the Quantity and Character of the Water supplied to towns and districts from these formations;—Second Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland;—Eighth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on an Investigation for the purpose of fixing a Standard of White Light;—Report of the Anthropometric Committee;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Second Report on the Marine Zoology of South Devon;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on accessions to our knowledge of the Chiroptera during the past two years (1878–80);—Preliminary Report on the accurate measurement of the specific inductive capacity of a good Sprengel Vacuum, and the specific resistance of gases at different pressures;—Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St. Petersburg;—First Report on the Caves of the South of Ireland;—Report on the Investigation of the Natural History of Socotra;—Report on the German and other systems of teaching the Deaf to speak;—Report of the Committee for considering whether it is important that H.M. Inspectors of Elementary Schools should be appointed with reference to their ability for examining in the scientific specific subjects of the Code in addition to other matters;—On the Anthracite Coal and Coalfield of South Wales;—Report on the present state of our knowledge of Crustacea (Part V.);—Report on the best means for the Development of Light from Coal-gas of different qualities (Part II.);—Report on Palæontological and Zoological Researches in Mexico;—Report on the possibility of establishing a 'Close Time' for Indigenous Animals;—Report on the present state of our knowledge of Spectrum Analysis;—Report on Patent Legislation;—Preliminary Report on the present Appropriation of Wages, &c.;—Report on the present state of knowledge of the application of Quadratures and Interpolation to Actual Data;—The French Deep-sea Exploration in the Bay of Biscay;—Third Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—List of Works on the Geology, Mineralogy, and Palæontology of Wales (to the end of 1873);—On the recent Revival in Trade.

Together with the Transactions of the Sections, Dr. A. C. Ramsay's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTY-FIRST MEETING, at York, August and September 1881, *Published at* £1 4*s*.

CONTENTS :—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms;—Report on Recent Progress in Hydrodynamics (Part I.);—Report on Meteoric Dust;—Second Report on the Calculation of Sun-heat Coefficients;—Fourteenth Report on Underground Temperature;—Report on the Measurement of the Lunar Disturbance of Gravity;—Second Report on an Investigation for the purpose of fixing a Standard of White Light;—Final Report on the Thermal Conductivities of certain Rocks;—Report on the manner in which Rudimentary Science should be taught, and how Examinations should be held therein, in Elementary Schools;—Third Report on the Tertiary Flora of the North of Ireland;—Report on the Method of Determining the Specific Refraction of Solids

from their Solutions;—Fourth Report on the Stationary Tides in the English Channel and in the North Sea, &c.;—Second Report on Fossil Polyzoa;—Report on the Maintenance of the Scottish Zoological Station;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Migration of Birds;—Report on the Natural History of Socotra;—Report on the Natural History of Timor-laut;—Report on the Marine Fauna of the Southern Coast of Devon and Cornwall;—Report on the Earthquake Phenomena of Japan;—Ninth Report on the Erratic Blocks of England, Wales, and Ireland;—Second Report on the Caves of the South of Ireland;—Report on Patent Legislation;—Report of the Anthropometric Committee;—Report on the Appropriation of Wages, &c.;—Report on Observations of Luminous Meteors;—Report on Mathematical Tables;—Seventh Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to Towns and Districts from these Formations;—Report on the present state of our Knowledge of Spectrum Analysis;—Interim Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—On some new Theorems on Curves of Double Curvature;—Observations of Atmospheric Electricity at the Kew Observatory during 1880;—On the Arrestation of Infusorial Life by Solar Light;—On the Effects of Oceanic Currents upon Climates;—On Magnetic Disturbances and Earth Currents;—On some Applications of Electric Energy to Horticultural and Agricultural purposes;—On the Pressure of Wind upon a Fixed Plane Surface;—On the Island of Socotra;—On some of the Developments of Mechanical Engineering during the last Half-Century.

Together with the Transactions of the Sections, Sir John Lubbock's Address, and Recommendations of the Association and its Committees.

REPORT OF THE FIFTY-SECOND MEETING, at Southampton, August 1882, *Published at* £1 4*s*.

CONTENTS:—Report on the Calculation of Tables of Fundamental Invariants of Binary Quantics;—Report (provisional) of the Committee for co-operating with the Meteorological Society of the Mauritius in their proposed publication of Daily Synoptic Charts of the Indian Ocean from the year 1861;—Report of the Committee appointed for fixing a Standard of White Light;—Report on Recent Progress in Hydrodynamics (Part II.);—Report of the Committee for constructing and issuing practical Standards for use in Electrical Measurements;—Fifteenth Report on Underground Temperature, with Summary of the Results contained in the Fifteen Reports of the Underground Temperature Committee;—Report on Meteoric Dust;—Second Report on the Measurement of the Lunar Disturbance of Gravity;—Report on the present state of our Knowledge of Spectrum Analysis;—Report on the Investigation by means of Photography of the Ultra-Violet Spark Spectra emitted by Metallic Elements, and their combinations under varying conditions;—Report of the Committee for preparing a new Series of Tables of Wave-lengths of the Spectra of the Elements;—Report on the Methods employed in the Calibration of Mercurial Thermometers;—Second Report on the Earthquake Phenomena of Japan;—Eighth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Water supplied to various Towns and Districts from these Formations;—Report on the Conditions under which ordinary Sedimentary Materials may be converted into Metamorphic Rocks;—Report on Explorations in Caves of Carboniferous Limestone in the South of Ireland;—Report on the Preparation of an International Geological Map of Europe;—Ninth Report on the Erratic Blocks of England, Wales, and Ireland;—Report on Fossil Polyzoa (Jurassic Species—British Area only);—Preliminary Report on the Flora of the 'Halifax Hard Bed,' Lower Coal Measures;—Report on the Influence of Bodily Exercise on the Elimination of Nitrogen;—Report of the Committee appointed for obtaining Photographs of the Typical Races in the British Isles;—Preliminary Report on the Ancient Earthwork in Epping Forest known as the Loughton Camp;—Second Report on the Natural History of Timor-laut;—Report of the Committee for carrying out the recommendations of the Anthropometric Committee of 1880, especially as regards the anthropometry of children and of females, and the more complete discussion of the collected facts;—Report on the Natural History of Socotra and the adjacent Highlands of Arabia and Somali Land;—Report on the

Maintenance of the Scottish Zoological Station;—Report on the Migration of Birds;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the Survey of Eastern Palestine;—Final Report on the Appropriation of Wages, &c.;—Report on the workings of the revised New Code, and of other legislation affecting the teaching of Science in Elementary Schools;—Report on Patent Legislation;—Report of the Committee for determining a Gauge for the manufacture of various small Screws;—Report on the best means of ascertaining the Effective Wind Pressure to which buildings and structures are exposed;—On the Boiling Points and Vapour Tension of Mercury, of Sulphur, and of some Compounds of Carbon, determined by means of the Hydrogen Thermometer;—On the Method of Harmonic Analysis used in deducing the Numerical Values of the Tides of long period, and on a Misprint in the Tidal Report for 1872;—List of Works on the Geology and Palæontology of Oxfordshire, of Berkshire, and of Buckinghamshire;—Notes on the oldest Records of the Sea-Route to China from Western Asia;—The Deserts of Africa and Asia;—State of Crime in England, Scotland, and Ireland in 1880;—On the Treatment of Steel for the Construction of Ordnance, and other purposes;—The Channel Tunnel;—The Forth Bridge.

Together with the Transactions of the Sections, Dr. C. W. Siemens's Address, and Recommendations of the Association and its Committees.

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FOR

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Prof. Allman, M.D., F.R.S.
Sir A. C. Ramsay, LL.D., F.R.S.
Sir John Lubbock, Bart., F.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., F.R.S.
Dr. T. A. Hirst, F.R.S.
Dr. Michael Foster, Sec. R.S.
George Griffith, Esq., M.A., F.C.S.
P. L. Sclater, Ph.D., F.R.S.

AUDITORS.

Professor G. C. Foster, F.R.S.
George Griffith, Esq., M.A., F.C.S.
John Evans, Esq., D.C.L., F.R.S.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1883.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough House, Burgess Hill, Sussex.
1881. *Abbott, R. T. G. Auburn Hill, Malton, Yorkshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, C.B., D.C.L., F.R.S., F.C.S., Director of the Chemical Establishment of the War Department. Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.
1873. ‡Abernethy, James. Ferry-hill, Aberdeen.
1860. ‡Abernethy, Robert. Ferry-hill, Aberdeen.
1873. *ABNEY, Captain W. DE W., R.E., F.R.S., F.R.A.S., F.C.S. Willeslie House, Wetherby-road, South Kensington, London, S.W.
1877. §Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1882. *Acland, Alfred Dyke. Oxford.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Francis E. Dyke, R.A. Oxford.
1873. *Acland, Rev. H. D., M.A. Nymet St. George, South Molton, Devon.

Year of
Election.

1873. *ACLAND, HENRY W. D., C.B., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 13 Vincent-square, Westminster, S.W.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.
1876. ‡Adams, James. 9 Royal-crescent West, Glasgow.
*ADAMS, JOHN COUCH, M.A., LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1871. §Adams, John R. 3 Queen's-gate-terrace, London, S.W.
1879. *ADAMS, Rev. THOMAS, M.A. Underhill, Low Fell, Gateshead.
1877. ‡ADAMS, WILLIAM. 3 Sussex-terrace, Plymouth.
1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.
1873. ‡Adams-Acton, John. Margutta House, 103 Marylebone-road, London, N.W.
1879. §Adamson, Robert, M.A., LL.D., Professor of Logic and Political Economy in Owens College, Manchester. 60 Parsonage-road, Withington, Manchester.
1860. *Adie, Patrick. Broadway, Westminster, S.W.
1865. *Adkins, Henry. Northfield, near Birmingham.
1883. §Adshead, Samuel. School of Science, Macclesfield.
1864. *Ainsworth, David, M.P. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Cumberland.
Ainsworth, Peter. Smithills Hall, Bolton.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S. The White House, Croom's Hill, Greenwich, S.E.
1871. §Aitken, John, F.R.S.E. Darroch, Falkirk, N.B.
Akroyd, Edward. Bankfield, Halifax.
1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.
1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.
1872. *Alcock, Thomas, M.D. Oakfield, Sale, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
1883. §Alexander, George. Milford, Co. Carlow.
1859. ‡ALEXANDER, General Sir JAMES EDWARD, K.C.B., K.C.L.S., F.R.S.E., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N.B.
1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.
1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.
1883. §Alger, Miss Ethel. Widey Court, near Plymouth.
1883. §Alger, W. H. Widey Court, near Plymouth.
1883. §Alger, Mrs. W. H. Widey Court, near Plymouth.
1867. ‡Alison, George L. C. Dundee.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.
1871. ‡ALLEN, ALFRED H., F.C.S. 1 Surrey-street, Sheffield.
1879. *Allen, Rev. A. J. C. Peterhouse, Cambridge.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.

Year of
Election.

1861. ‡Allen, Richard. Didsbury, near Manchester.
1852. *ALLEN, WILLIAM J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmoor, Parkstone, Dorset.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1883. §Amery, John Sparke. Druid House, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid House, Ashburton, Devon.
1876. ‡Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.
1878. ‡Anderson, Beresford. Saint Ville, Killiney.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1883. §Anderson, Miss Constance. Stonegate, York.
1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1876. ‡Anderson, Matthew. 137 St. Vincent-street, Glasgow.
1859. ‡ANDERSON, PATRICK. 15 King-street, Dundee.
1880. ‡*Anderson, Richard. New Malden, Surrey.*
1880. *ANDERSON, TEMPEST, M.D., B.Sc. 17 Stonegate, York.
1880. §Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. §Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1880. *Andrews, Thornton, M.I.C.E. Cefn Eithen, Swansea.
*ANDREWS, THOMAS, M.D., LL.D., F.R.S., Hon. F.R.S.E., M.R.I.A., F.C.S. Fortwilliam Park, Belfast.
1883. §Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S. 81 Ducie-grove, Oxford-street, Manchester.
1859. ‡Angus, John. Town House, Aberdeen.
1878. ‡Anson, Frederick H. 9 Delahay-street, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
APJOHN, JAMES, M.D., F.R.S., F.C.S., M.R.I.A., Professor of Mineralogy at Dublin University. South Hill, Blackrock, Co. Dublin.
1868. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *ARCHER, Professor THOMAS C., F.R.S.E., Director of the Museum of Science and Art, Edinburgh. St. Margaret's, Greenhill-place, Edinburgh.
1874. ‡Archer, William, F.R.S., M.R.I.A. St. Brendan's, Grosvenor-road East, Rathmines, Dublin.
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyleshire.
1883. §Armistead, Richard. Wharncliffe House, Beaufort-road, Brooklands, near Manchester.
1883. *Armistead, William. Wharncliffe House, Beaufort-road, Brooklands, near Manchester.
1861. ‡Armitage, William. 95 Portland-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1879. *Armstrong, Sir Alexander, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Albany, London, W.
1873. §ARMSTRONG, HENRY E., Ph.D., F.R.S., Sec.C.S. Technical College, Finsbury, London, E.C.
1878. ‡Armstrong, James. 28A Renfield-street, Glasgow.
Armstrong, Thomas. Higher Broughton, Manchester.

Year of Election.

1857. *ARMSTRONG, Sir WILLIAM GEORGE, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Jesmond Dene, Newcastle-upon-Tyne.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1873. §Ashton, John. Gorse Bank House, Windsor-road, Oldham.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
1875. *Aspland, W. Gaskell. Care of Manager, Union Bank, Chancery-lane, London, W.C.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1872. §Atchison, Arthur T., M.A. 60 Warwick-road, Earl's Court, London, S.W.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1865. ‡*Atkin, Alfred. Griffin's Hill, Birmingham.*
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1863. *Atkinson, G. Clayton. 21 Windsor-terrace, Newcastle-on-Tyne.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, John Hastings. 12 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 113 Abingdon-road, Kensington, London, W.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1883. §Atkinson, Miss Maria. The Laurels, Sale, Cheshire.
1881. ‡Atkinson, Robert William. Town Hall-buildings, Newcastle-on-Tyne.
Atkinson, William. Claremont, Southport.
1863. *ATTFIELD, Professor J., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Rectory, Stanton St. John, near Oxford.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1881. §AXON, W. E. A. Fern Bank, Higher Broughton, Manchester.
1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Technical College. 68 Sloane-street, London, S.W.
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1881. §Baden-Powell, George S., M.A., F.R.A.S., F.S.S. 8 St. George's-place, Hyde Park, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. §Bagrual, P. H. St. Stephen's Club, Westminster, S.W.

Year of
Election.

1883. §Baildon, Dr. 65 Manchester-road, Southport.
1883. §Bailey, Charles, F.L.S., Ashfield, College-road, Whalley Range, Manchester.
1870. §Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1878. ‡Bailey, John. 3 Blackhall-place, Dublin.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
1873. ‡Bain, Sir James. 3 Park-terrace, Glasgow.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, Sir EDWARD, J.P. Belgrave-mansions, Grosvenor-gardens, London, S.W.; and St. Ann's Hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1882. ‡Baker, Benjamin, M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. The Gables, Buxton.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1865. ‡Baker, Robert L. Barham House, Leamington.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. Moorland House, Stoke Bishop, near Bristol.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡BALFOUR, ISAAC BAYLEY, D.Sc., M.B., F.R.S.E., Professor of Botany in the University of Glasgow. Glasgow.
*BALFOUR, JOHN HUTTON, M.A., M.D., LL.D., F.R.S. L. & E., F.L.S., Emeritus Professor of Botany. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D. 16 Lower Fitzwilliam-street, Dublin.
*BALL, JOHN, M.A., F.R.S., F.L.S., M.R.I.A. 10 Southwell-gardens, South Kensington, London, S.W.
1866. *BALL, ROBERT STAWELL, M.A., LL.D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. The Observatory, Dunsink, Co. Dublin.
1878. ‡BALL, VALENTINE, M.A., F.R.S., F.G.S., Director of the Museum of Science and Art, Dublin.
1883. §Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1883. §Balloch, Miss. Glasgow.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1882. §Bance, Major Edward. Limewood, The Avenue, Southampton.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1879. ‡Banham, H. French. Mount View, Glossop-road, Sheffield.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1883. §Banning, John J. 28 Westcliffe-road, Southport.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Bankhead, Broxton, Chester.
1859. ‡Barbour, George F. 11 George-square, Edinburgh.

Year of Election.

*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A. Bury Hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1881. §Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. G. Above Bar, Southampton.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Rotherham, Yorkshire.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡BARKLY, Sir HENRY, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, London, S.W.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
1883. §Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. §Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1857. ‡BARLOW, PETER WILLIAM, F.R.S., F.G.S. 26 Great George-street, Westminster, S.W.
1873. §BARLOW, W. H., M.Inst.C.E., F.R.S. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. Harlow, Essex.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
Barnes, Thomas Addison. Brampton Collieries, near Chesterfield.
1839. *Barnett, Richard, M.R.C.S. 18 Albany-terrace, Britannia-square, Worcester.
1881. ‡Barr, Archibald, B.Sc. Castlehead, Paisley.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1883. §Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. §Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1872. *BARRETT, W. F., F.R.S.E., M.R.I.A., F.C.S., Professor of Physics in the Royal College of Science, Dublin.
1883. §Barrett, William Scott. Winton Lodge, Crosby, near Liverpool.
1874. *Barrington, R. M. Fassaroe, Bray, Co. Wicklow.
1874. §Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1881. §BARRON, G. B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1862. *BARRY, CHARLES. 15 Pembridge-square, London, W.
1883. §Barry, Charles E. 15 Pembridge-square, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
Barstow, Thomas. Garrow Hill, near York.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.

Year of Election.

1855. ‡Bartholomew, Hugh. New Gasworks, Glasgow.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1873. ‡Bartley, George C. T. St. Margaret's House, Victoria-street, London, S.W.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, London, N.
1866. ‡*Bassett, Richard. Pelham-street, Nottingham.*
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡Bastian, H. Charlton, M.D., M.A., F.R.S., F.L.S., Professor of Pathological Anatomy at University College, London. 20 Queen Anne-street, London, W.
1848. ‡Bate, C. Spence, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1883. §Bateman, A. E. Board of Trade, London, S.W.
1873. *Bateman, Daniel. Carpenter-street, above Broad-street, Philadelphia, United States.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.R.G.S., F.L.S. 9 Hyde Park-gate South, London, W.
1842. *Bateman, John Frederic La Trobe, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. 16 Great George-street, London, S.W.
1864. ‡Bates, Henry Walter, F.R.S., F.L.S., Assist.-Sec. R.G.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡Bath and Wells, The Right Rev. Lord Arthur Hervey, Lord Bishop of. The Palace, Wells, Somerset.
1881. *Bather, Francis Arthur. Red House, Roehampton, Surrey, S.W.
1869. ‡Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, W.
1863. §Bauerman, H., F.G.S. 41 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1867. ‡Baxter, The Right Hon. William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Thomas Sebastian, M.A. Hatherop Castle, Fairford, Gloucestershire.
1860. *Beale, Lionel S., M.D., F.R.S., Professor of Pathological Anatomy in King's College. 61 Grosvenor-street, London, W.
1882. §Beamish, Major A.W., R.E. Cranbury-terrace, Southampton.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1870. §Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
1883. §Beard, Mrs. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Ash Mount, Rotherham.

Year of Election.

1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.M.S., F.S.S. 18 Piccadilly, London, W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Lieut.-Colonel George G., F.R.G.S. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 68 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. 155 Shrewsbury-street, Whalley Range, Manchester.
1860. ‡BECKLES, SAMUEL H., F.R.S., F.G.S. 9 Grand-parade, St. Leonard's-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D., F.R.S. Clifton, Bristol.
1858. ‡Bedford, James. Woodhouse Cliff, near Leeds.
1878. ‡Bedson, P. Phillips, D.Sc., F.C.S. College of Physical Science, Newcastle-on-Tyne.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. ‡Bell, Asahel P. St. Anne's-street, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1855. ‡*Bell, Capt. Henry. Chalfont Lodge, Cheltenham.*
1880. §Bell, Henry Oswin. 13 Northumberland-terrace, Tynemouth.
1879. ‡Bell, Henry S. Kenwood Bank, Sharrow, Sheffield.
1862. *BELL, ISAAC LOWTHIAN, F.R.S., F.C.S., M.I.C.E. Rounton Grange, Northallerton.
1875. ‡Bell, James, F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *Bell, J. Carter, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡Bell, R. Bruce, C.E. Institution of Engineers, Glasgow.
1863. *Bell, Thomas. Palazo Vitoria, Bilbao, Spain.
1867. ‡Bell, Thomas. Belmont, Dundee.
1882. §Bell, W. Alexander, B.A. 3 Madeira-terrace, Kemp Town, Brighton.
1875. ‡*Bell, William. Witford House, Briton Ferry, Glamorganshire.*
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1882. §Bellingham, William. 2 Edinburgh Mansions, Victoria-street, London, S.W.
1864. *Bendyshe, T. 3 Sea View-terrace, Margate.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. §Bennett, Henry. Bedminster, Bristol.
1881. §Bennett, John R. Bedminster, Bristol.
1883. *Bennett, Laurence Henry. Trinity College, Oxford.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishophill Junior, York.
1870. *Bennett, William. Heysham Tower, Lancaster.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 5 Tavistock-square, London, W.C.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.

Year of Election.

1848. ‡BENTHAM, GEORGE, F.R.S., F.R.G.S., F.L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 2 Portland-place, London, W.
1863. §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College, London. 38 Penywern-road, Earl's Court, London, S.W.
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1868. ‡BERKELEY, Rev. M. J., M.A., F.R.S., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1881. ‡*Berkley, H. Rorke. Prestwich, Manchester.*
1848. ‡*Berrington, Arthur V. D. Woodlands Castle, near Swansea.*
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, Sir HENRY, F.R.S. Denmark Hill, London, S.E.
1882. §Bessemer, Henry, jun. Mount House, Hythe, Southampton.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1883. §Betley, Ralph, F.G.S. Mining School, Wigan.
1876. *Bettany, G. T., M.A., B.Sc., Lecturer on Botany at Guy's Hospital, London. 2 Eckington-villas, Ashbourne-grove, East Dulwich, S.E.
1883. §Bettany, Mrs. 2 Eckington-villas, Ashbourne-grove, East Dulwich, S.E.
1880. *Bevan, Rev. James Oliver, M.A. 72 Beaufort-road, Edgbaston, Birmingham.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. Shireshead Vicarage, Garstang.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1882. §Biggs, C. H. W., F.C.S. 1 Bloomfield, Bromley, Kent.
1864. ‡Biggs, Robert. 16 Green Park, Bath.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1881. ‡Binnie, Alexander R., F.G.S. Town Hall, Bradford, Yorkshire.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1879. ‡Binns, E. Knowles, F.R.G.S. 216 Heavygate-road, Sheffield.
Birchall, Edwin, F.L.S. Douglas, Isle of Man.
Birchall, Henry. College House, Bradford.
1880. §Bird, Henry, F.C.S. South Down, near Devonport.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
1871. *BISCHOF, GUSTAV. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1883. §Bishop, John le Marchant. 100 Mosley-street, Manchester.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1877. ‡BLACHFORD, The Right Hon. Lord, K.C.M.G. Cornwood, Ivybridge.
1881. §Black, William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. 14 Victoria-road, Kensington, London, W.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1883. §Blackie, Adrian. 22 Devonshire-street, Manchester.

Year of
Election.

1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John Stewart, M.A., Professor of Greek in the University of Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1883. §Blacklock, Mrs. Sea View, Lord-street, Southport.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London, E.C.
1878. §Blair, Matthew. Oakshaw, Paisley.
1883. §Blair, Mrs. Oakshaw, Paisley.
1863. ‡Blake, C. Carter, D.Sc. Westminster Hospital School of Medicine, Broad Sanctuary, Westminster, S.W.
1849. *BLAKE, HENRY WOLLASTON, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1883. *BLAKE, Rev. J. F., M.A., F.G.S. University College, Nottingham.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1878. ‡Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1861. §Blakiston, Matthew, F.R.G.S. Free Hills, Burledon, Hants.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1869. ‡BLANFORD, W. T., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, London, W.
*BLOMEFIELD, Rev. LEONARD, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1880. §Bloxam, G. W., M.A., F.L.S. The Hut, Upper Teddington, Surrey.
1883. §Blumberg, Dr. 65 Hoghton-street, Southport.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1883. §Blyth, Miss Phœbe. 3 South Mansion House-road, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, near Accrington.
1867. ‡Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1883. §Bodman, Miss Caroline M. Roslyn, Eltham-road, Lee, Kent.
1859. *BOHN, HENRY G., F.L.S., F.R.A.S., F.R.G.S., F.S.S. North End House, Twickenham.
1871. ‡Bohn, Mrs. North End House, Twickenham.
1881. ‡Bojanowski, Dr. Victor de, Consul-General for Germany. 27 Finsbury-circus, London, E.C.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
Bond, Henry John Hayes, M.D. Cambridge.
1883. §Bonney, Frederic. Oriental Club, Hanover-square, London, W.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, London, N.W.
1871. §BONNEY, Rev. THOMAS GEORGE, D.Sc., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. (SECRETARY.) 22 Albemarle-street, London, W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. ‡Booth, James. Elmfield, Rochdale.
1883. §Booth, James. Hazelhurst, Turton.
1883. §Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.
1861. *Booth, William. Hollybank, Cornbrook, Manchester.
1876. ‡Booth, Rev. William H. Yardley, Birmingham.
1883. §Boothroyd, Benjamin. Rawlinson-road, Southport.
1880. §Boothroyd, Samuel. Warley House, Southport.

Year of Election.

1861. *Borchardt, Louis, M.D. Barton Arcade, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 7 Goldney-road, Paddington, London, W.
1876. *Bosanquet, R. H. M., M.A., F.C.S., F.R.A.S. St. John's College, Oxford.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §Bothamley, Charles H. Yorkshire College, Leeds.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. *Bottomley, James Thomson, M.A., F.R.S.E., F.C.S. 2 Eton-terrace, Hillhead, Glasgow.
Bottomley, William. Southampton-place, Reading.
1876. ‡Bottomley, William, jun. 6 Rokeley-terrace, Hillhead, Glasgow.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1868. ‡Boulton, W. S. Norwich.
1883. §Bourdas, Isaiah. 59 Belgrave-road, London, S.W.
1883. §Bourne, A. G. University College, London, W.C.
1866. §Bourne, Stephen, F.S.S. Abberley, Wallington, Surrey.
1872. ‡Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.
1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1881. *Bower, F. O. Elmscroft, Ripon, Yorkshire.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1880. ‡Bowly, Christopher. Cirencester.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, Sir William, Bart., F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Prince's-park, Liverpool.
1863. ‡Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡Boyle, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1872. *Brabrook, E. W., F.S.A. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1870. ‡*Brace, Edmund. 3 Spring-gardens, Kelvinside, Glasgow.*
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1880. ‡Bradford, H. Stretton House, Walters-road, Swansea.
Bradshaw, William. Slade House, Green-walk, Bowdon, Cheshire.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡Brady, George S., M.D., F.R.S., F.L.S., Professor of Natural History in the College of Physical Science, Newcastle-on-Tyne. 22 Fawcett-street, Sunderland.
1862. §Brady, Henry Bowman, F.R.S., F.L.S., F.G.S. Hillfield, Gateshead.
1880. *Brady, Rev. Nicholas, M.A. Wennington, Essex.
1875. ‡Bragge, William, F.S.A., F.G.S. Shirle Hill, Birmingham.
1864. §Braham, Philip, F.C.S. 7 Miles's-buildings, Bath.
1870. ‡Braidwood, Dr. Delemere-terrace, Birkenhead.

Year of
Election.

1879. ‡Bramley, Herbert. Claremont-crescent, Sheffield.
1865. §BRAMWELL, Sir FREDERICK J., F.R.S., M.Inst.C.E. 5 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1852. ‡BRAZIER, JAMES S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡*Brazill, Thomas. 12 Holles-street, Dublin.*
1869. *BREADALBANE, The Right Hon. the Earl of. Taymouth Castle N.B.; and Carlton Club, Pall Mall, London, S.W.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. 54 Old Broad-street, London, E.C.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. ‡Briant, T. Hampton Wick, Kingston-on-Thames.
1867. ‡BRIDGMAN, WILLIAM KENCELEY. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. ‡Brierley, Joseph, C.E. New Market-street, Blackburn.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1863. *BRIGHT, Sir CHARLES TILSTON, M.Inst.C.E., F.G.S., F.R.G.S., F.R.A.S. 20 Bolton-gardens, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
BRIGHT, The Right Hon. JOHN, M.P. Rochdale, Lancashire.
1868. ‡Brine, Captain Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1879. ‡Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *BRITTAIN, W. H. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, W.C.
1859. *BRODHURST, BERNARD EDWARD, F.R.C.S., F.L.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. Ventnor House, Canterbury.
1865. ‡BRODIE, Rev. PETER BELLINGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡*Bromby, J. H., M.A. The Charter House, Hull.*
1878. *Brook, George, F.L.S. Fernbrook, Huddersfield, Yorkshire.
1880. ‡Brook, G. B. Brynsyfi, Swansea.
1881. §Brook, Robert G. Rowen-street, St. Helen's, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1878. ‡Brooke, Sir Victor, Bart., F.L.S. Colebrook, Brookeborough, Co. Fermanagh.
1863. ‡Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawtenstall, Manchester.
Brooks, William. Ordfall Hill, East Retford, Nottinghamshire.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1883. §Brotherton, E. A. Bolton Bridge-road, Ilkley, Leeds.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.

Year of Election.

1871. ‡Brown, David. 93 Abbey-hill, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. §Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. §Brown, George. Henley Villa, Ealing, Middlesex, W.
1883. §Brown, Mrs. H. Bientz. 9 Ladywell-park, London, S.E.
1883. §Brown, Mrs. Helen. 52 Grange Loan, Edinburgh.
1870. §BROWN, HORACE T. 47 High-street, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1883. §Brown, Miss Isabella Spring. 52 Grange Loan, Edinburgh.
1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Edenderry House, Belfast.
1881. *Brown, John, M.D. 66 Bank-parade, Burnley, Lancashire.
1882. §Brown, John. Swiss Cottage, Park-valley, Nottingham.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Haddington, N.B.
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.
1882. *Brown, Mrs. Mary. Burnley, Lancashire.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. Fersley, Rydal-road, Streatham, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Evesham Lawn, Pittville, Cheltenham.
*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.
1855. ‡Brown, William. 33 Berkeley-terrace, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41A New-street, Birmingham.
1879. ‡Browne, J. Crichton, M.D., LL.D., F.R.S. L. & E. 7 Cumberland-terrace, Regent's Park, London, N.W.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.
1875. ‡Browne, Walter R., M.A., M.Inst.C.E. 38 Belgrave-road, London, S.W.
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. ‡Browning, John, F.R.A.S. 63 Strand, London, W.C.
1883. §Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *BRUNLEES, JAMES, F.R.S.E., F.G.S., M.Inst.C.E. 5 Victoria-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡BRUNTON, T. LAUDER, M.D., F.R.S. 50 Welbeck-street, London, W.
1878. §Brutton, Joseph. Yeovil.
1877. ‡Bryant, George. 82 Claverton-street, Pimlico, London, S.W.
1875. ‡Bryant, G. Squier. 15 White Ladies'-road, Clifton, Bristol.
1875. ‡*Bryant, Miss S. A. The Castle, Denbigh.*
1861. ‡*Bryce, James. York-place, Higher Broughton, Manchester.*
BRYCE, Rev. R. J., LL.D. Fitzroy-avenue, Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡BUCCLEUCH AND QUEENSBERRY, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith House, Edinburgh.
1871. §BUCHAN, ALEXANDER, M.A., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.

Year of Election.

1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. 12 Barnard-road, Birkenhead, Cheshire.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG. 10 Moray-place, Edinburgh.
1883. §Buckland, Miss A. W. 54 Doughty-street, London, W.C.
1864. §BUCKLE, Rev. GEORGE, M.A. The Rectory, Weston-super-Mare.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1848. *BUCKMAN, Professor JAMES, F.L.S., F.G.S. Bradford Abbas, Sherborne, Dorsetshire.
1880. §Buckney, Thomas, F.R.A.S. Little Thurlow, Suffolk.
1869. ‡Bucknill, J. C., M.D., F.R.S. E 2 Albany, London, W.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1875. §Budgett, Samuel. Cotham House, Bristol.
1883. §Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1871. ‡Bulloch, Matthew. 4 Bothwell-street, Glasgow.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. §Bulpit, Rev. F. W. Crossens Rectory, Southport.
1845. *BUNBURY, Sir CHARLES JAMES FOX, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1865. ‡Bunce, John Mackray. 'Journal' Office, New-street, Birmingham.
1863. §Bunning, T. Wood. Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
1842. *Burd, John. 5 Gower-street, London, W.C.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. §Burdett-Coutts, W. L. A. B. 1 Stratton-street, Piccadilly, London, W.
1874. ‡*Burdon, Henry, M.D. Clandeboye, Belfast.*
1883. *Burne, Colonel Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 85 Warrington-crescent, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1877. ‡Burns, David, C.E. Alston, Carlisle.
1883. §Burr, Percy J. 20 Little Britain, London, E.C.
1881. §Burroughs, S. M. 7 Snow-hill, London, E.C.
1883. *Burrows, Abraham. Greenhall, Atherton, near Manchester.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1877. ‡Burt, J. Kendall. Kendal.
1874. ‡Burt, Rev. J. T. Broadmoor, Berks.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1879. ‡*Bury, Percy B. Cambridge.*
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *BUSK, GEORGE, F.R.S., F.L.S., F.G.S. 32 Harley-street, Cavendish-square, London, W.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, London, S.W.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Ph.D. 298 Regent-street, London, W.
1883. §Buxton, Miss F. M. Newnham College, Cambridge.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 7 Grosvenor-crescent, London, S.W.
1883. §Buxton, Rev. Thomas, M.A. 19 Westcliffe-road, Birkdale, Southport.

Year of
Election.
1872. ‡Buxton, Sir Thomas Fowell, Bart., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Cheshire.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. §Byrom, John R. Royal Mills, Droylesden.
1875. ‡Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡Caird, Edward B. 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Belleaire, Greenock.
1875. ‡Caldicott, Rev. J. W., D.D. The Grammar School, Bristol.
1877. ‡Caldwell, Miss. 2 Victoria-terrace, Portobello, Edinburgh.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1854. ‡*Calver, Captain E. K., R.N., F.R.S. The Grange, Redhill, Surrey.*
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, CHARLES A., M.D. 15 Pembroke-road, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1881. ‡Cameron, Major-General, C.B. 3 Driffield-terrace, York.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S., F.S.S. 17 Southwell-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
1883. §Campbell, H. J. Streatham, Surrey.
1874. Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
1872. ‡CAMPBELL, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire.
1876. ‡Campbell, James A. 3 Claremont-terrace, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1859. ‡Campbell, William. Dunmore, Argyllshire.
CAMPBELL-JOHNSTON, ALEXANDER ROBERT, F.R.S. 84 St. George's-square, London, S.W.
1876. §Campion, Frank, F.G.S., F.R.G.S. The Mount, Duffield-road, Derby.
1862. *CAMPION, Rev. WILLIAM M., D.D. Queen's College, Cambridge.
1882. §Candy, F. H. 71 High-street, Southampton.
1880. ‡Capper, Robert. Westbrook, Swansea.
1883. §Capper, Mrs. R. Westbrook, Swansea.
1873. *Carbutt, Edward Hamer, M.P., C.E. 19 Hyde Park-gardens, London, W.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
1883. §Carey-Hobson, Mrs. 54 Doughty-street, London, W.C.
1877. ‡Carkeet, John, C.E. 3 St. Andrew's-place, Plymouth.
1876. ‡Carlile, Thomas. 5 St. James's-terrace, Glasgow.
CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., Lord Bishop of Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.

Year of Election.

1871. ‡CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. *CARPENTER, P. HERBERT, M.A. Eton College, Windsor.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. 36 Craven-park, Harlesden, London, N.W.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1883. §Carson, John. 51 Royal Avenue, Belfast.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E., F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 62 Elizabeth-street, Liverpool.
1883. §Carter, W. C. Manchester and Salford Bank, Southport.
1883. §Carter, Mrs. Manchester and Salford Bank, Southport.
1878. *Cartwright, E. Henry. Magherafelt Manor, Co. Derry.
1870. §Cartwright, Joshua, A.I.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, Facundo. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1883. §Carver, James. Garfield House, Elm-avenue, Nottingham.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. The Lawns, Highgate, London, N.
1878. ‡Casey, John, LL.D., F.R.S., M.R.I.A., Professor of Higher Mathematics in the Catholic University of Ireland. 2 Iona-terrace, South Circular-road, Dublin.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Saville Park, Halifax.
Castle, Charles. Clifton, Bristol.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.
1853. ‡*Cator, John B., Commander R.N. 1 Adelaide-street, Hull.*
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, M.A., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathematics in the University of Cambridge. (PRESIDENT.) Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1879. §Chadburn, Alfred. Brincliffe Rise, Sheffield.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. Lynncourt, Broadwater Down, Tunbridge Wells.
1860. ‡CHADWICK, DAVID. The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.
1883. §Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1883. §Chalk, William. 24 Gloucester-road, Birkdale, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. §Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1865. ‡CHAMBERLAIN, The Right Hon. J. H., M.P., F.R.S. Southbourne, Augustus-road, Birmingham.

Year of Election.

1883. §Chambers, Benjamin. Hawkshead-street South, Southport.
1883. §Chambers, Charles, F.R.S. Colába Observatory, Bombay.
1883. §Chambers, Mrs. Colába Observatory, Bombay.
1883. §Chambers, Charles, jun. 7 Promenade, Southport.
1842. Chambers, George. High Green, Sheffield.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
1877. *CHAMPERNOWNE, ARTHUR, M.A., F.G.S. Dartington Hall, Totnes, Devon.
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Woodlands, Halifax.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1877. §Chapman, T. Algernon, M.D. Burghill, Hereford.
1866. ‡*Chapman, William. The Park, Nottingham.*
1871. ‡Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1874. ‡Charles, John James, M.A., M.D. 11 Fisherwick-place, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 277 Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.
1883. §Chater, Rev. John. Part-street, Southport.
1867. *Chatwood, Samuel, F.R.G.S. Irwell House, Drinkwater Park, Prestwich.
1883. §Chawner, W., M.A. Emanuel College, Cambridge.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1874. *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1879. *Chesterman, W. Broomsgrove-road, Sheffield.
1879. ‡Cheyne, Commander J. P., R.N. 1 Westgate-terrace, West Brompton, London, S.W.
1872. §CHICHESTER, The Right Hon. the Earl of. Stanmer House, Lewes.
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.
1883. §Chinery, Edward F. Monmouth House, Lymington.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1882. §Chorley, George. Midhurst, Sussex.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
1875. *Christopher, George, F.C.S. 8 Rectory-grove, Clapham, London, S.W.
1876. *CHRYSTAL, G., M.A., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §CHURCH, A. H., M.A., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1881. §Churchill, Lord Alfred Spencer. 16 Rutland-gate, London, S.W.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1882. ‡Churton, Frederick. Albion-place, Southampton.
1868. ‡Clabburn, W. H. Thorpe, Norwich.

Year of Election.

1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1869. *Clapp, Frederick. Roseneath, St. James's-road, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
1877. *Clark, F. J. Street, Somerset.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1877. Clark, G. T. 44 Berkeley-square, London, W.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 20 Bootham, York.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. §Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
Clarke, George. Mosley-street, Manchester.
1872. *Clarke, Hyde. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡Clarke, John Henry. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. 2 Beech-grove, Holyrood, Prestwich.
1877. ‡Clarke, Professor John W. University of Chicago, Illinois.
1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1883. §Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1850. ‡Cleghorn, Hugh, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §Cleland, John, M.D., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1857. ‡*Clements, Henry. Dromin, Listowel, Ireland.*
‡*Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.*
1873. §Cliff, John, F.G.S. Linnburn, Ilkley, near Leeds.
1883. §Clift, Frederic, LL.D. Norwood, Surrey.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1883. *Clowes, Frank, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. University College, Nottingham.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
Cobb, Edward. 6 Lansdown-place East, Bath.
1864. ‡Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Professor of Botany and Helminthology in the Royal Veterinary College, London. 74 Portsdown-road, Maida Hill, London, W.
1864. *Cochrane, James Henry. Lochiar, Cork.

Year of Election.

1883. §Cockshott, J. J. 74 Belmont-street, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Highfield, Manchester-road, Bolton.
1881. §Coffin, Walter Harris, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1876. ‡Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.
1853. ‡Colchester, William, F.G.S. Springfield House, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1876. ‡Colebrooke, Sir T. E., Bart., M.P., F.R.G.S. 14 South-street, Park-lane, London, W.; and Abington House, Abington, N.B.
1860. ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 2 Gipsy Hill-villas, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡COLLINS, J. H., F.G.S. Rio Tinto Mines, Huelva, Spain.
1876. ‡Collins, William. 3 Park-terrace East, Glasgow.
1883. §Collis, W. Elliott. 3 Lincoln's-Inn-fields, London, W.C.
1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1882. §Colmer, Joseph G. Office of the High Commissioner for Canada, 9 Victoria-chambers, London, S.W.
1870. ‡Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
*COMPTON, The Very Rev. Lord ALWYNE, D.D., Dean of Worcester. The Deanery, Worcester.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Hope House, College Park East, Belfast.
1881. ‡CONROY, Sir JOHN, Bart. Arborfield, Reading, Berks.
1876. ‡Cook, James. 162 North-street, Glasgow.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Southampton.
1876. *COOKE, CONRAD W., C.E. 2 Victoria-mansions, Victoria-street, London, S.W.
1881. ‡Cooke, F. Bishophill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishophill, York.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1883. §Cooke-Taylor, R. Whateley. Frenchwood House, Preston.
1883. §Cooke-Taylor, Mrs. Frenchwood House, Preston.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1863. ‡*Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.*
1869. §Cooling, Edwin, F.R.G.S. Mile Ash, Derby.
1883. §Coomer, John. 53 Albert-road, Southport.
1883. §Cooper, George B. 67 Great Russell-street, London, W.C.

Year of Election.

1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1879. §Cooper, Thomas. Rose Hill, Rotherham, Yorkshire.
1846. ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡Copeland, Ralph, Ph.D., F.R.A.S. Dun Echt, Aberdeen.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1863. ‡Coppin, John. North Shields.
1842. Corbett, Edward. Ravenoak, Cheadle Hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology in Queen's College, Cork.
1881. §Cordeaux, John. Great Cotes, Ulceby, Lincolnshire.
1883. *Core, Thomas H. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
1883. §Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
1870. Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazenose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, D.D., Bishop of Edinburgh. Edinburgh.
1874. *Cotterill, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
1879. §Cottrill, Gilbert I. Shepton Mallett, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. ‡Courtauld, John M. Bocking Bridge, Braintree, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
1876. ‡Cowan, J. B., M.D. Helensburgh, N.B.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.G.S. Comptons Lea, Horsham.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Lyndhurst, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park, Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 85 Rann-street, Birmingham.
1883. §Crabtree, William, C.E. Manchester-road, Southport.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1857. ‡*Crampton, Rev. Josiah. Nettlebeds, near Oxford.*
1879. §Crampton, Thomas Russell. 19 Ashley-place, London, S.W.

Year of
Election.

1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1876. ‡Crawford, Chalmond. Ridemon, Crosscar.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, LL.D., F.R.S., F.R.A.S. The Observatory, Dun Echt, Aberdeen.
1871. ‡Crawshaw, Edward. Burnley, Lancashire.
1883. *Crawshaw, Edward. 25 Tollington Park, London, N.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1879. ‡Creswick, Nathaniel. Handsworth Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
1880. *Crisp, Frank, B.A., LL.B., F.L.S. 5 Lansdowne-road, Notting Hill, London, W.
1878. ‡Croke, John O'Byrne, M.A. The French College, Blackrock, Dublin.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1866. ‡*Cronin, William. 4 Brunel-terrace, Nottingham.*
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §Crookes, William, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. *Crosfield, William, jun. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1883. §Cross, Rev. Prebendary, LL.B. Part-street, Southport.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §Crosskey, Rev. H. W., LL.D., F.G.S. 117 Gough-road, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1883. §Crowder, Robert. Stannix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1861. §Crowley, Henry. Trafalgar-road, Birkdale Park, Southport.
1883. §Crowther, Elon. Cambridge-road, Huddersfield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *Culverwell, Edward P. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. §Culverwell, T. J. H. Litfield House, Clifton.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. The Oaks, Handforth, Manchester.
1882. *Cunningham, Major Allan, R.E., A.I.C.E. Care of Messrs. Grindlay's Agency, Calcutta.
1877. ‡Cunningham, D. J., M.D. Royal College of Surgeons in Ireland, Stephen's Green, Dublin.

Year of
Election.

1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Rev. William, M.A., D.Sc. Trinity Hall, Cambridge.
1855. ‡*Cunningham, William A. 2 Broadwalk, Buxton.*
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1881. ‡Curley, T., C.E., F.G.S. Hereford.
1867. *Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, ARTHUR HILL, LL.D. 1 Hume-street, Dublin.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1883. §Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1863. ‡*Daglish, John. Hetton, Durham.*
1854. ‡Daglish, Robert, M.Inst.C.E. Orrell Cottage, near Wigan.
1883. §Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1863. ‡Dale, J. B. South Shields.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H., F.R.S., F.L.S. Sheffield College, Glossop-road, Sheffield.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡*Dalrymple, Colonel. Troup, Scotland.*
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
1862. ‡DANBY, T. W., M.A., F.G.S. 1 Westbourne-terrace-road, London, W.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1883. §Darbishire, S. D., M.D. 60 High-street, Oxford.
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
1882. ‡DARWIN, FRANCIS, M.A., F.R.S., F.L.S. Down, Beckenham, Kent.
1881. *DARWIN, GEORGE HOWARD, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Trinity College, Cambridge.
1878. *Darwin, Horace. 66 Hills-road, Cambridge.
1882. §Darwin, W. E., F.G.S. Bassett, Southampton.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1878. ‡D'Aulmay, G. 22 Upper Leeson-street, Dublin.
1872. ‡Davenport, John T. 64 Marine Parade, Brighton.
1880. §Davey, Henry, M.Inst.C.E. Rupert Lodge, Grove-road, Headingley, Leeds.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1871. ‡Davidson, James. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡DAVIDSON, THOMAS, LL.D., F.R.S., F.G.S. 9 Salisbury-road West, Brighton.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. 88 Seel-street, Liverpool.
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1873. *Davis, Alfred. Parliament Mansions, London, S.W.

Year of Election.

1870. *Davis, A. S. 6 Paragon-buildings, Cheltenham.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1881. §Davis, George E. The Willows, Fallowfield, Manchester.
1882. §Davis Henry C. Berry Pomeroy, Springfield-road, Brighton.
1873. *DAVIS, JAMES W., F.G.S., F.S.A. Chevinedge, near Halifax.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. 36 Royal York-crescent, Clifton, Bristol.
1883. §Davis, Joseph, J.P. Park-road, Southport.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1883. §Davis, Robert Frederick, M.A. Earlsfield, Wandsworth Common, London, S.W.
1882. §Davis, W. H. Gloucester Lodge, Portswood, Southampton.
1873. ‡*Davis, William Samuel.* 1 *Cambridge-villas, Derby.*
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, EDMUND W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1860. *Dawes, John T., F.G.S. Blaen-y-Roe, St. Asaph, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
Dawson, John. Barley House, Exeter.
1855. ‡DAWSON, JOHN W., C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal of M'Gill College, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1879. ‡Day, Francis. Kenilworth House, Cheltenham.
1871. ‡DAY, ST. JOHN VINCENT, C.E., F.R.S.E. 166 Buchanan-street, Glasgow.
1870. §DEACON, G. F., M.I.C.E. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. Spring Hill College, Moseley, near Birmingham.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E.
1882. *DE CHAUMONT, FRANÇOIS, M.D., F.R.S., Professor of Hygiène in the Royal Victoria Hospital, Netley.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1854. *DE LA RUE, WARREN, M.A., D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1879. ‡De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.
1870. ‡De Meschin, Thomas, M.A., LL.D. 4 Hare-court, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
1875. ‡Denny, William. Seven Ship-yard, Dumbarton.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1874. §DE RANCE, CHARLES E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *DERBY, The Right Hon. the Earl of, M.A., LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.

Year of
Election.

1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.

De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.

1869. ‡Devon, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.

*Devonshire, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.

1868. ‡Dewar, James, M.A., F.R.S. L. & E., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. 19 Brookside, Cambridge.

1881. ‡Dewar, Mrs. 19 Brookside, Cambridge.

1883. §Dewar, James. South Queensferry, West Lothian, N.B.

1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 2 Southwick-place, Hyde Park, London, W.

1873. *Dew-Smith, A. G., M.A. 7a Eaton-square, London, S.W.

1883. §Dickinson, A. P. Fair Elms, Blackburn.

1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.

1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.

1867. ‡Dickson, Alexander, M.D., Professor of Botany in the University of Edinburgh. 11 Royal-circus, Edinburgh.

1881. §Dickson, Edmund. West Cliff, Preston.

1883. §Dickson, T. A. West Cliff, Preston.

1862. *Dilke, The Right Hon. Sir Charles Wentworth, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.

1877. ‡Dillon, James, C.E. Stratford House, Silchester-road, Glengeary, Co. Dublin.

1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwerne, near Swansea.

1872. ‡Dines, George. Woodside, Hersham, Walton-on-Thames.

1869. ‡Dingle, Edward. 19 King-street, Tavistock.

1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.

1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.

1868. ‡Dittmar, William, F.R.S., F.C.S., F.R.S.E., Professor of Chemistry in Anderson's College, Glasgow.

1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.

1883. §Dixon, Miss E. 2 Cliff-terrace, Kendal.

1853. ‡Dixon, Edward. Wilton House, Southampton.

1879. *Dixon, Harold B., M.A., F.C.S. Trinity College, Oxford.

*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.

1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.

1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.

1878. *Dobson, G. E., M.A., M.B., F.R.S., F.L.S. Royal Victoria Hospital, Netley, Southampton.

1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.

1875. *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.

1870. *Dodd, John. 53 Cable-street, Liverpool.

1876. ‡Dodds, J. M. 15 Sandyford-place, Glasgow.

Dolphin, John. Delves House, Berry Edge, near Gateshead.

1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.

1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.

Year of Election.

1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1882. §Donaldson, John. Tower House, Chiswick, Middlesex.
1873. ‡Donham, Thomas. Huddersfield.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1874. ‡Donnell, Professor, M.A. 76 Stephen's-green South, Dublin.
1861. ‡Donnelly, Colonel, R.E. South Kensington Museum, London, W.
1881. §Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. *Doughty, Charles Montagu. Theberton Hall, Saxmundham, Suffolk.
1876. *Douglas, Rev. G. C. M. 18 Royal-crescent West, Glasgow.
1877. *Douglass, Sir James N., C.E. Trinity House, London, E.C.
1878. ‡Douglass, William. 104 Baggot-street, Dublin.
1883. §Dove, Arthur. Crown Cottage, York.
1870. ‡Dowie, J. Muir. Achanacreagh, Morvern, N.B.
1876. ‡Dowie, Mrs. Muir. Achanacreagh, Morvern, N.B.
1878. ‡Dowling, Thomas. Claireville House, Terenure, Dublin.
1882. §Downes, Rev. W. Kentisbeare, Collumpton, Devon.
1857. ‡DOWNING, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.
1878. ‡Dowse, The Right Hon. Baron. 38 Mountjoy-square, Dublin.
1865. *Dowson, E. Theodore, F.M.S. Geldeston, near Beccles, Suffolk.
1881. §Dowson, Joseph Emerson, C.E. 3 Great Queen-street, London, S.W.
1883. §Draper, William. De Grey House, St. Leonard's, York.
1868. ‡DRESSER, HENRY E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873. §DREW, FREDERIC, F.G.S., F.R.G.S. Eton College, Windsor.
1869. §Drew, Joseph, LL.D., F.R.A.S., F.G.S. Weymouth.
1879. ‡Drew, Joseph, M.B. Foxgrove-road, Beckenham, Kent.
1865. ‡*Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.*
1879. ‡Drew, Samuel, M.D., D.Sc., F.R.S.E. 10 Laura-place, Bath.
1872. **Druce, Frederick. 27 Oriental-place, Brighton.*
1874. ‡*Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.*
1870. §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1883. §Duck, A. E. Southport.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Holme House, Columbia-road, Oxton, Birkenhead.
1867. *DUFF, The Right Hon. MOUNTSTUART ELPHINSTONE GRANT-, F.R.S., F.R.G.S., Governor of Madras. Care of W. Hunter, Esq., 14 Adelphi-court, Union-street, Aberdeen.
1852. ‡Dufferin and Clandeboye, The Right Hon. the Earl of, K.P., K.C.B., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1883. §Duke, Frederic. Conservative Club, Hastings.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859. ‡*Duncan Charles. 52 Union-place, Aberdeen*
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1867. ‡DUNCAN, PETER MARTIN, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 4 St. George's-terrace, Regent's-Park-road, London, N.W.
1880. §Duncan, William S. 79 Wolverhampton-road, Stafford.

Year of Election.

1881. §Duncombe, The Hon. Cecil. Nawton Grange, York.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1853. *Dunlop, William Henry. Annanhill, Kilmarnock, Ayrshire.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1876. *Dunn, James. 64 Robertson-street, Glasgow.
1882. §Dunn, J. T. College of Physical Science, Newcastle-on-Tyne.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1866. ‡Duprey, Perry. Woodberry Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1883. §Eagar, Rev. Thomas. The Rectory, Ashton-under-Lyne.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1833. *Earnshaw, Rev. Samuel, M.A. 14 Broomfield, Sheffield.
1874. §Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1833. §Eastham, Silas. 50 Leyland-road, Southport.
1871. *Easton, Edward, C.E., F.G.S. 11 Delahay-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. §Eastwood, Miss. Littleover Grange, Derby.
1870. §Eaton, Richard. 1 Stafford-street, Derby.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1883. *Ecliott, E. B., M.A. Queen's College, Oxford.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Syward Lodge, Dorchester.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 72 Portsdown-road, London, W.
1883. §Edmonds, William. Wiscombe Park, Honiton, Devon.
1883. §Edmunds, L. H., D.Sc. 8 Grafton-street, Piccadilly, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1855. *Edwards, Professor J. Baker, Ph.D., D.C.L. Montreal, Canada.
1873. ‡*Elcock, Charles. 30 Lyme-street, Shakspere-street, Ardwick, Manchester.*
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1883. §Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.

Year of Election.

1880. *Elliot, Colonel Charles, C.B. Hazelbank, Murrayfield, Midlothian, N.B.

1855. ‡Elliot, Robert, F.B.S.E. Wolfelee, Hawick, N.B.

1861. *Elliot, Sir Walter, K.C.S.I., F.R.S., F.L.S. Wolfelee, Hawick, N.B.

1864. ‡Elliott, E. B. Washington, United States.

1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.

Elliott, John Fogg. Elvet Hill, Durham.

1879. §Elliott, Joseph W. Post Office, Bury, Lancashire.

1864. *Ellis, Alexander John, B.A., F.R.S., F.S.A. 25 Argyll-road, Kensington, London, W.

1877. ‡Ellis, Arthur Devonshire. School of Mines, Jermyn-street, London, S.W.; and Thurnscoe Hall, Rotherham, Yorkshire.

1875. *Ellis, H. D. 67 Ladbroke Grove-road, Notting Hill, London, W.

1883. §Ellis, John. 17 Church-street, Southport.

1880. *Ellis, John Henry. New Close, Cambridge-road, Southport.

1864. *Ellis, Joseph. Hampton Lodge, Brighton.

1864. ‡Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.

*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.

1869. ‡Ellis, William Horton. Hartwell House, Exeter.

Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.

1862. ‡Elphinstone, H. W., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.

1883. §Elwes, George Robert. Bossington, Bournemouth.

1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.

1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.

1858. ‡Empson, Christopher. Bramhope Hall, Leeds.

1866. ‡Enfield, Richard. Low Pavement, Nottingham.

1866. ‡Enfield, William. Low Pavement, Nottingham.

1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.

1869. ‡*English, J. T. Stratton, Cornwall.*

Enniskillen, The Right Hon. William Willoughby, Earl of, LL.D., D.C.L., F.R.S., F.G.S., M.R.I.A. 65 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.

1883. §Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.

1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.

1844. ‡Erichsen, John Eric, F.R.S., F.R.C.S., Professor of Clinical Surgery in University College, London. 6 Cavendish-place, London, W.

1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.

1862. *Esson, William, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.

1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.

Estcourt, Rev. W. J. B. Long Newton, Tetbury.

1869. ‡Etheridge, Robert, F.R.S.L. & E., F.G.S., Assistant Keeper (Geological and Palæontological Department) Natural History Museum (British Museum). 19 Halsey-street, Cadogan-place, London, S.W.

1883. §Eunson, Henry J. 20 St. Giles-street, Northampton.

1881. ‡Evans, Alfred. Exeter College, Oxford.

1870. *Evans, Arthur John, F.S.A. Nash Mills, Hemel Hempstead.

1865. *Evans, Rev. Charles, M.A. The Rectory, Solihull, Birmingham.

1876. ‡Evans, Captain Sir Frederick J. O., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. 116 Victoria-street, Westminster, S.W.

Year of Election.

1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, Surrey.
1861. *EVANS, JOHN, D.C.L., LL.D., Treas.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempstead.
1883. §Evans, J. C. Nevill-street, Southport.
1883. §Evans, Mrs. J. C. Nevill-street, Southport.
1881. §Evans, Lewis. Picton Villa, Carmarthen.
1876. ‡Evans, Mortimer, C.E. 97 West Regent-street, Glasgow.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Heathfield, Alleyn Park, Lower Norwood, S.E.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. The Spring, Kenilworth.
1871. §Eve, H. Weston, M.A. University College, London, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in Queen's College, Belfast. Lennox-vale, Belfast.
1880. ‡Everingham, Edward. St. Helen's-road, Swansea.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1883. §Eves, Miss. Uxbridge.
1881. ‡Ewart, J. Cossar, M.D., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, William, M.P. Glenmachan, Belfast.
1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *Ewing, James Alfred, B.Sc., F.R.S.E., Professor of Mechanical Engineering in the University of Tokio, Japan. 12 Laurel Bank, Dundee.
1883. §Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warrens, near Lyndhurst, Hants.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1865. ‡FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1876. ‡Fairlie, James M. Charing Cross Corner, Glasgow.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1878. *Fairlie, Robert F. Palace-chambers, Victoria-street, Westminster, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1883. §Fallon, Rev. W. S. 1 St. Alban's-terrace, Cheltenham.
1877. §Faraday, F. J., F.L.S, F.S.S. College Chambers, 17 Brazenose-street, Manchester.
1879. *Farnworth, Ernest. Swindon, near Dudley.
1883. §Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. §Farnworth, William. 86 Preston New-road, Blackburn.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1866. *FARRAR, Rev. FREDERICK WILLIAM, M.A., D.D., F.R.S., Archdeacon of Westminster. St. Margaret's Rectory, Westminster, S.W.
1883. §Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. Ebor Villa, Godwin-road, Clive-vale, Hastings.
1883. §Faulding, Mrs. Ebor Villa, Godwin-road, Clive-vale, Hastings.

Year of Election.

1859. *FAWCETT, The Right Hon. HENRY, M.A., M.P., F.R.S., Professor of Political Economy in the University of Cambridge. 51 The Lawn, South Lambeth-road, London, S.W.; and 18 Brookside, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1873. *Fazakerley, Miss. The Castle, Denbigh.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *FELLOWS, FRANK P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.
1883. §Fenwick, E. H. 29 Harley-street, London, W.
1876. *Fergus, Andrew, M.D. 3 Elmbank-crescent, Glasgow.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. §Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Sir Samuel, LL.D., Q.C. 20 Great George's-street North, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1883. §Fernald, H. P. Alma House, Cheltenham.
1863. *FERNIE, JOHN. Bonchurch, Isle of Wight.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, D.D., F.R.S., Vice-Chancellor of the University of Cambridge. Caius College Lodge, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., F.R.S., Professor of Forensic Medicine in King's College. 16 Upper Berkeley-street, London, W.
1882. §Fewings, James, B.A., B.Sc. The Grammar School, Southampton.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1869. *FIELD, ROGERS, B.A., C.E. 5 Cannon-row, Westminster, S.W.
1882. §Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 10 Lyndhurst-road, Hampstead, London, N.W.
1883. §Finch, Mrs. Gerard. 10 Lyndhurst-road, Hampstead, London, N.W.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1878. *Findlater, William, M.P. 22 Fitzwilliam-square, Dublin.
1883. §Finney, John Douglass. 27 Porchester-terrace, London, W
1883. §Finney, Mrs. J. D. 27 Porchester-terrace, London, W.
1883. §Finney, Miss. 27 Porchester-terrace, London, W.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *FISCHER, WILLIAM L. F., M.A., LL.D., F.R.S. St. Andrews, Scotland.
1858. ‡Fishbourne, Admiral E. G., R.N. 26 Hogarth-road, Earl's Court-road, London, S.W.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1879. ‡Fisher, William. Norton Grange, near Sheffield.
1875. *Fisher, W. W., M.A., F.C.S. 2 Park-crescent, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.

Year of
Election.

1871. *Fison, Frederick W., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. ‡Fitch, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1883. §Fitch, Rev. J. J. Ivyholme, Southport.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §Fitzgerald, George Francis, M.A., F.R.S. Trinity College, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1881. ‡Fitzsimmons, Henry, M.D. Minster-yard, York.
1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 121 Hagley-road, Birmingham.
1881. ‡Fleming, Rev. Canon James, B.D. The Residence, York.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §Fletcher, Alfred E. 5 Edge-lane, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1869. ‡Fletcher, Lavington E., M.Inst.C.E. 41 Corporation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡Flower, William Henry, LL.D., F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. 7 The Terrace, Putney, S.W.
1881. ‡Foljambe, Cecil G. S., M.P. 2 Carlton House-terrace, Pall Mall, London, S.W.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1879. ‡Foote, Harry D'Oyley, M.D. Rotherham, Yorkshire.
1880. ‡Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *Forbes, George, M.A., F.R.S.E. 34 Great George-street, London, S.W.
1883. §Forbes, Henry O., F.Z.S. Rubislaw Den, Aberdeen.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
1875. *Fordham, H. George, F.G.S. Odsey Grange, Royston, Cambridgeshire.
*Forrest, William Hutton. 1 Pitt-terrace, Stirling.
1883. §Formby, R. Formby, near Liverpool.
1867. ‡Forster, Anthony. Finlay House, St. Leonard's-on-Sea.
1858. *Forster, The Right Hon. William Edward, M.P., F.R.S. 80 Eccleston-square, London, S.W.; and Wharfeside, Burley-in-Wharfedale, Leeds.
1883. §Forsyth, A. R. University College, Liverpool.
1854. *Fort, Richard. Read Hall, Whalley, Lancashire.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1882. §Forward, Henry. 3 Burr-street, London, E.
1870. ‡Forwood, Sir William B. Hopeton House, Seaforth, Liverpool
1875. ‡Foster, A. Le Neve. East Hill, Wandsworth, Surrey, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *Foster, Clement Le Neve, B.A., D.Sc., F.G.S. Llandudno.
1883. §Foster, Mrs. C. Le Neve. Llandudno.
1857. *Foster, George Carey, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 12 Hilldrop-road, London, N.

Year of Election.

1881. ‡Foster, J. L. Ogleforth, York.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., Sec. R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Trinity College, and Great Shelford, near Cambridge.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. **Foster, S. Lloyd. Brundall Lodge, Ealing, Middlesex, W.*
1873. *Foster, William. Harrowins House, Queensbury, Yorkshire.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1876. *Fowler, John. 4 Kelvin Bank-terrace, Glasgow.
1882. ‡FOWLER, JOHN, M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1870. *Fowler, Robert Nicholas, M.A., M.P., F.R.G.S. 50 Cornhill, London, E.C.
1883. *Fox, Charles. Fore-street, Kingsbridge, Devon.
1883. §Fox, Charles Douglas, C.E. 5 Delahay-street, Westminster, S.W.
1860. *Fox, Rev. Edward, M.A. Upper Heyford, Banbury.
1883. §Fox, Howard, United States Consul. Falmouth.
1876. *Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
1876. ‡Fox, St. G. Lane. 9 Sussex-place, London, S.W.
1881. *FOXWELL, HERBERT S., M.A., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1866. *Francis, G. B. Inglesby House, Stoke Newington-green, London, N.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, M.D., D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. The Yews, Reigate Hill, Surrey.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
1882. §Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S. L. & E. 37 Melville-street, Edinburgh.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester.
1877. §Freeman, Francis Ford. Black Friars House, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1880. ‡Freeman, Thomas. Brynhyfryd, Swansea.
1841. Freeth, Major-General S. 30 Royal-crescent, Notting Hill, London, W.
Frere, George Edward, F.R.S. Roydon Hall, Diss, Norfolk.
1869. ‡FRERE, The Right Hon. Sir H. BARTLE E., Bart., G.C.S.I., G.C.B., F.R.S., F.R.G.S. Athenæum Club, London, S.W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
1857. *Frith, Richard Hastings, C.E., M.R.I.A., F.R.G.S.I. 48 Summerhill, Dublin.
1883. §Froane, William. Beech House, Birkdale, Southport.

Year of
Election.

1869. ‡*Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.*
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. §Frost, Captain H., J.P. West Wratting, Cambridgeshire.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse Hill, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
Fry, Francis. Cotham, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
1872. *Fuller, Rev. A. Pallant, Chichester.
1859. ‡Fuller, Frederick, M.A. 9 Palace-road, Surbiton.
1869. ‡Fuller, George, M.Inst.C.E., Professor of Engineering in Queen's College, Belfast. 14 College-gardens, Belfast.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Aswardby Hall, Spilsby.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
Galbraith, Rev. J. A., M.A., M.R.I.A. Trinity College, Dublin.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 225 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1875. §Galloway, W. Cardiff.
1860. *Galton, Captain Douglas, C.B., D.C.L., F.R.S., F.L.S., F.G.S., F.R.G.S. (General Secretary.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *Galton, Francis, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡Galton, John C., M.A., F.L.S. 40 Great Marlborough-street, London, W.
1870. §Gamble, Lieut.-Colonel D. St. Helen's, Lancashire.
1870. ‡Gamble, J. C. St. Helen's, Lancashire.
1872. *Gamble, John G., M.A. Capetown. (Care of Messrs. Ollivier and Brown, 37 Sackville-street, Piccadilly, London. W.)
1877. ‡Gamble, William. St. Helen's, Lancashire.
1868. ‡Gamgee, Arthur, M.D., F.R.S., F.R.S.E., Professor of Physiology in Owens College, Manchester. Fairview, Princes-road, Fallowfield, Manchester.
1883. §Gant, Major John Castle. St. Leonard's.
1882. *Gardner, H. Dent, F.R.G.S. 25 Northbrook-road, Lee, Kent.
1882. ‡Gardner, John Starkie, F.G.S. Park House, St. John's Wood Park, London, N.W.
1862. ‡Garner, Robert, F.L.S. Stoke-upon-Trent.
1865. ‡Garner, Mrs. Robert. Stoke-upon-Trent.
1882. §Garnett, William, M.A. University College, Nottingham.
1873. ‡*Garnham, John. 123 Bunhill-row, London, E.C.*
1883. §Garson, J. G., M.D. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.

Year of
Election.

1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinstead, Sussex.
1875. ‡Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S., M.D. Newton Abbot, Devon
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. §Geddes, John. 25 Portland-street, Southport.
1859. ‡Geddes, William D., M.A., Professor of Greek in King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. ‡Geikie, Archibald, LL.D., F.R.S. L. & E., F.G.S., Director-General of the Geological Survey of the United Kingdom. Geological Survey Office, Jermyn-street, London, S.W.
1871. ‡Geikie, James, LL.D., F.R.S. L. & E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 10 Bright's-crescent, Mayfield, Edinburgh.
1883. §Gell, Mrs. Seedley Lodge, Pendleton, Manchester.
1882. §Genese, R. W., M.A., Professor of Mathematics in University College, Aberystwith.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1870. ‡Gerstl, R., F.C.S. University College, London, W.C.
1870. *Gervis, Walter S., M.D., F.G.S. Ashburton, Devonshire.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1874. ‡Gibson, The Right Hon. Edward, Q.C., M.P. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., F.G.S. 1 Randolph Cliff, Edinburgh.
*Gibson, George Stacey. Saffron Walden, Essex.
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 10 Parkfield-road, Prince's Park, Liverpool.
1842. Gilbert, Joseph Henry, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1883. §Gilbert, Mrs. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1883. §Gilbert, Thomas. Derby-road, Southport.
1859. *Gilchrist, James, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1882. ‡Giles, Alfred, M.P., M.I.C.E. Cosford, Godalming.
1878. §Giles, Oliver. Park Side, Cromwell-road, St. Andrew's, Bristol.
Giles, Rev. William. Netherleigh House, near Chester.
1878. ‡Gill, Rev. A. W. H. 44 Eaton-square, London, S.W.
1871. *Gill, David. The Observatory, Cape Town.
1881. ‡Gill, H. C. Bootham, York.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡Gill, Thomas. 4 Sydney-place, Bath.
1861. *Gilroy, George. Woodlands, Parbold, near Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1876. ‡Gimingham, Charles H., F.C.S. 45 St. Augustine's-road, Camden-square, London, N.W.
1867. §Ginsburg, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1869. ‡Girdlestone, Rev. Canon E., M.A. Olveston, Almondbury, Gloucestershire.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1883. *Gladstone, Miss. 17 Pembridge-square, London, W.

Year of Election.

1883. *Gladstone, Miss E. A. 17 Pembridge-square, London, W.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Brighton.
1883. *Gladstone, Miss Isabella M. 17 Pembridge-square, London, W.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, London, W.
1875. *Glaisher, Ernest Henry. 1 Dartmouth-place, Blackheath, London, S.E.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., M.A., F.R.S., F.R.A.S. Trinity College, Cambridge.
1883. §Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S. Trinity College, Cambridge.
1881. §Gleadow, Frederic. 13 Park-square, Leeds.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡*Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London, W.C.*
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
1874. ‡*Glover, Thomas. 77 Claverton-street, London, S.W.*
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S. 10 Chandos-street, Cavendish-square, London, W.
1883. §Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.R.G.S., F.Z.S. Deepdale, Reigate.
1846. ‡GODWIN-AUSTEN, ROBERT A. C., B.A., F.R.S., F.G.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1877. ‡GOFF, JAMES. 11 Northumberland-road, Dublin.
1881. ‡Goldschmidt, Edward. Nottingham.
1873. ‡Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1878. ‡Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1842. *GOODMAN, JOHN, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville, M.A. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Lambourne Rectory, Romford.
1883. §Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.
1871. **Gordon, Joseph Gordon, F.C.S. 20 King-street, St. James's, London, S.W.*
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1875. *Gotch, Francis. Stokes Croft, Bristol.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.I.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.

Year of Election.

1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *Graham, Cyril, C.M.G., F.L.S., F.R.G.S. Walton House, Ryde, Isle of Wight.
1875. ‡Grahame, James. Auldhouse, Pollokshaws, near Glasgow.
1852. *Grainger, Rev. Canon John, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1871. ‡Grant, Sir Alexander, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1870. ‡Grant, Colonel James A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1855. *Grant, Robert, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡Grantham, Richard B., M.Inst.C.E., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1881. ‡Graves, E. 22 Trebovir-road, Earl's Court-road, London, S.W.
1874. ‡Graves, Rev. James, B.A., M.R.I.A. Inisnag Glebe, Stonyford, Co. Kilkenny.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1864. ‡Gray, Jonathan. Summerhill House, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. ‡*Gray, J. Macfarlane. 127 Queen's-road, Peckham, London, S.E.*
1878. ‡*Gray, Matthew Hamilton. 14 St. John's Park, Blackheath, London, S.E.*
1878. ‡*Gray, Robert Kaye. 14 St. John's Park, Blackheath, London, S.E.*
1881. ‡Gray, Thomas. 21 Haybrom-crescent, Glasgow.
1883. §Gray, Thomas. Spittal Hill, Morpeth.
1873. ‡Gray, William, M.R.I.A. 6 Mount Charles, Belfast.
*Gray, Colonel William. Farley Hall, near Reading.
1883. §Gray, William Lewis. 36 Gutter-lane, London, E.C.
1883. §Gray, Mrs. W. L. 36 Gutter-lane, London, E.C.
1883. §Greathead, J. H. 8 Victoria-chambers, London, S.W.
1866. §Greaves, Charles Augustus, M.B., LL.B. 101 Friar-gate, Derby.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 3 South-square, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1879. ‡Green, A. F. 15 Ashwood-villas, Headingley, Leeds.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1882. §Greenhill, A. G., M.A., Professor of Mathematics at the Royal Artillery Institution, Woolwich. Emmanuel College, Cambridge.

Year of Election.

1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. ‡Greenwood, Frederick. School of Medicine, Leeds.
1862. *Greenwood, Henry. 32 Castle-street, and the Woodlands, Anfield-road, Anfield, Liverpool.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1883. §Greenwood, J. G., LL.D., Vice-Chancellor of Victoria University. Owens College, Manchester.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.M.G. 2 Delahay-street, Westminster, S.W.
1883. §Gregson, G. E. Ribble View, Preston.
1861. *Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1881. §Gregson, William. Baldersby, Thirsk.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
1875. ‡Grey, Mrs. Maria G. 18 Cadogan-place, London, S.W.
1871. *Grierson, Samuel, Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1875. ‡Grieve, David, F.R.S.E., F.G.S. 2 Victoria-terrace, Portobello, Edinburgh.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1859. *Griffith, George, M.A., F.C.S. Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1870. §Griffith, Rev. Henry, F.G.S. Barnet, Herts.
1870. ‡*Griffith, N. R. The Coppa, Mold, North Wales.*
Griffiths, Rev. John, M.A. Wadham College, Oxford.
1847. ‡Griffiths, Thomas. Bradford-street, Birmingham.
1879. §Griffiths, Thomas, F.C.S., F.S.S. Silverdale, Oxton, Birkenhead.
1875. ‡Grignon, James, H.M. Consul at Riga. Riga.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1881. ‡Gripper, Edward. Nottingham.
1864. ‡Groom-Napier, Charles Ottley. 18 Elgin-road, St. Peter's Park, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. 42 Ovington-square, London, S.W.
Grove, The Hon. Sir William Robert, Knt., M.A., D.C.L., F.R.S. 115 Harley-street, London, W.
1863. *Groves, Thomas B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡Grubb, Howard, F.R.S., F.R.A.S. 40 Leinster-square, Rathmines, Dublin.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *Guise, Lieut.-Colonel Sir William Vernon, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, John, M.A., F.G.S. Irstedd Rectory, Norwich.
1877. ‡Gunn, William, F.G.S. Barnard Castle, Darlington.
1866. ‡Günther, Albert C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, South Kensington, S.W.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.

Year of Election.

1868. *Gurney, John. Sprouston Hall, Norwich.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1859. ‡GUTHRIE, FREDERICK, B.A., F.R.S. L. & E., Professor of Physics in the Royal School of Mines. Science Schools, South Kensington, London, S.W.
1883. §Guthrie, Malcolm. 2 Parkfield-road, Liverpool.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡GWYTHER, R. F., M.A. Owens College, Manchester.

1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1881. §HADDON, ALFRED CORT, B.A., F.Z.S., Professor of Zoology in the Royal College of Science, Dublin.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1869. ‡*Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.*
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1870. ‡*Halhead, W. B. 7 Parkfield-road, Liverpool.*
1883. §Haliburton, Robert Grant. National Club, Whitehall, London, S.W.
HALIFAX, The Right Hon. Viscount, G.C.B., F.R.G.S. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. *Hall, Miss Emily. Bowdon, Cheshire.
1881. §Hall, Frederick Thomas, F.R.A.S. Moore-place, Esher, Surrey.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡*Hall, John Frederic. Ellerker House, Richmond, Surrey.*
1872. *Hall, Captain Marshall. 13 Old-square, Lincoln's Inn, London, W.C.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. ‡Hall, Walter. 11 Pier-road, Erith.
1883. *Hall, Miss Wilhelmina. The Gore, Eastbourne.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1868. *HALLETT, WILLIAM HENRY, F.L.S. Buckingham House, Marine Parade, Brighton.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Holmeside, Hazelwood, Derby.
1883. *Hamel, Egbert D. de. Bole Hall, Tamworth.
1869. §Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1881. *Hammond, Robert. 110 Cannon-street, London, E.C.
1878. ‡Hanagan, Anthony. Luckington, Dalkey.
1878. §Hance, Edward M., LL.B. 6 Sea Bank-avenue, Egremont, Cheshire.
1875. ‡Hancock, C. F., M.A. 36 Blandford-square, London, N.W.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, N.

Year of
Election.
1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D., M.R.I.A. 64 Upper Gardiner-street, Dublin.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. (GENERAL SECRETARY.) Cowley Grange, Oxford.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrooke House, Exeter.
1877. §Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1874. ‡Hardman, E. T., F.C.S. 14 Hume-street, Dublin.
1872. ‡Hardwicke, Mrs. 192 Piccadilly, London, W.
1880. §Hardy, John. 118 Embden-street, Manchester.
*HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. §Hargreaves, Miss H. M. Oakhurst, West Haughton, near Bolton.
1883. §Hargreaves, Thomas. 69 Alexandra-road, Southport.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1876. ‡Harker, Allen. 17 Southgate-street, Gloucester.
1878. *Harkness, H. W. Sacramento, California.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. Stanbridge, Staplefield, Crawley, Sussex.
1883. §Harland, Miss S. 25 Acomb-street, Greenheys, Manchester.
1883. *Harley, Miss Clara. College-place, Huddersfield.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
1883. *Harley, Harold. College-place, Huddersfield.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. College-place, Huddersfield.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *Harmer, Sidney F., B.Sc. King's College, Cambridge.
1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
*Harris, Alfred. Lunefield, Kirkby-Lonsdale, Westmoreland.
1883. §Harris, Charles. Derwent Villa, Whalley Range, Manchester.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1842. *Harris, G. W., M.Inst.C.E. Mount Gambier, South Australia.
1863. ‡Harris, T. W. Grange, Middlesbrough-on-Tees.
1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. ‡Harrison, George. Barnsley, Yorkshire.
1873. ‡Harrison, George, Ph.D., F.L.S., F.C.S. 14 St. James's-row, Sheffield.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. 22 Connaught-street, Hyde Park, London, W.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.

Year of
Election.

1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1883. §Harrison, Thomas. 34 Ash-street, Southport.
1854. ‡Harrowby, The Right Hon. the Earl of. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1876. *Hart, Thomas. Brooklands, Blackburn.
1881. §Hart, Thomas, F.G.S. Yewbarrow, Grange-over-Sands, Carnforth.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1854. §Hartnup, John, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1882. §Haslam, George James, M.D. Royal Hospital, Salford, Lancashire.
1875. ‡Hastings, G. W., M.P. Barnard's Green House, Malvern.
1857. ‡Haughton, Rev. Samuel, M.A., M.D., D.C.L., LL.D., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Dublin.
1874. ‡Hawkins, B. Waterhouse, F.G.S. Century Club, East Fifteenth-street, New York.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, London, S.W.
*Hawkshaw, Sir John, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., M.Inst.C.E., F.G.S. 50 Harrington-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. §Hawksley, Thomas, M.Inst.C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *Hay, Rear-Admiral the Right Hon. Sir John C. D., Bart., C.B., M.P., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1869. ‡Hayward, J. High-street, Exeter.
1858. *Hayward, Robert Baldwin, M.A., F.R.S. The Park, Harrow.
1879. *Hazlehurst, George S. The Elms, Runcorn.
1851. §Head, Jeremiah, M.Inst.C.E., F.C.S. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1883. §Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. §Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. §Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1871. §Healey, George. Brantfield, Bowness, Windermere.
1883. *Heap, Ralph, jun. 2 Lulworth-road, Birkdale, Southport.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1883. §Heape, Charles. 14 Hawkshead-street, Southport.

Year of Election.

1883. §Heape, Joseph R. 96 Mereland-terrace, Rochdale.
1882. *Heape, Walter. New Museums, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1865. ‡Hearder, William. Rocombe, Torquay.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1883. §Heath, Dr. 46 Hoghton-street, Southport.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §Heathfield, W. E., F.C.S., F.R.G.S., F.R.S.E. 12 Alexandra-villas, Brighton; and Arthur's Club, St. James's, London, S.W.
1883. §Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.
1833. ‡Heaviside, Rev. Canon J. W. L., M.A. The Close, Norwich.
1855. ‡Hector, James, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Forster, M.D., F.R.S.E., Professor of Chemistry in the University of St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1882. ‡Hedger, Philip. Cumberland-place, Southampton.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1867. ‡Henderson, Alexander. Dundee.
1845. ‡*Henderson, Andrew.* 120 *Gloucester-place, Portman-square, London, W.*
1873. *Henderson, A. L. 49 King William-street, London, E.C.
1883. §Henderson, Mrs. A. L. 49 King William-street, London, E.C.
1880. *Henderson, Commander W. H., R.N. H.M.S. *Nelson*, Australia.
1876. *Henderson, William. Williamfield, Irvine, N.B.
1856. ‡Hennessy, Henry G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. 3 Idrone-terrace, Blackrock, Co. Dublin.
1857. ‡Hennessy, Sir John Pope, K.C.M.G., Governor and Commander-in-Chief of Mauritius.
1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Applied Mathematics in University College, London. Meldorf Cottage, Kemplay-road, Hampstead, London, N.W.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell, M.P. Stratheden House, Hyde Park, London, W.
1874. ‡Henry, Rev. P. Shuldam, D.D., M.R.I.A. Belfast.
*Henry, William Charles, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.
1870. ‡Henty, William. 12 Medina-villas, Brighton.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Baldwyns, Bexley, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1856. ‡*Hepworth, Rev. Robert.* 2 *St. James's-square, Cheltenham.*
1882. §Herbert, The Hon. Auberon. Ashley, Arnewood Farm, Lymington.
1866. ‡Herrick, Perry. Bean Manor Park, Loughborough.
1871. *Herschel, Professor Alexander S., B.A., F.R.A.S. College of Science, Newcastle-on-Tyne.
1883. §Herschel, Miss F. Collingwood, Hawkhurst, Kent.
1874. §Herschel, Lieut.-Colonel John, R.E., F.R.S., F.R.A.S. Collingwood, Hawkhurst, Kent.
1883. §Hesketh, Colonel E. Fleetwood. Meol's Hall, Southport.
1865. ‡Heslop, Dr. Birmingham.
1883. §Hewson, Thomas. 3 Queen's-road, Tunbridge Wells.
1881. ‡Hey, Rev. William Croser, M.A. Clifton, York.

Year of
Election.

1882. §Heycock, Charles T., B.A. King's College, Cambridge.
1883. §Heyes, John Frederick. 5 Rufford-road, Fairfield, Liverpool.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1879. ‡Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
*HEYWOOD, JAMES, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1861. *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1881. §Hick, Thomas, B.A., B.Sc. 2 George's-terrace, Harrogate.
1875. ‡HICKS, HENRY, M.D., F.G.S. Hendon Grove, Hendon, Middlesex, N.W.
1877. §HICKS, W. M., M.A. 18 Newbould-lane, Broomhill, Sheffield.
1864. *HIERN, W. P., M.A. Castle House, Barnstaple.
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡HIGGINS, CLEMENT, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1854. ‡HIGGINS, Rev. HENRY H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Holmwood, Turvey, near Bedford.
1870. ‡Higginson, Alfred. 135 Tulse Hill, London, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1880. ‡Hill, Benjamin. Cwmdwr, near Clydach, Swansea.
1883. §Hill, Berkeley, M.B., Professor of Clinical Medicine in University College, London. 55 Wimpole-street, London, W.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathley, East Grinstead.
1881. §HILL, Rev. EDWIN, M.A., F.G.S. St. John's College, Cambridge.
1857. §Hill, John, C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. ‡Hill, Lawrence. The Knowe, Greenock.
1881. ‡Hill, Pearson. 50 Belsize Park, London, N.W.
1872. *Hill, Rev. Canon, M.A., F.G.S. Sheering Rectory, Harlow.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 225 Oxford-street, London, W.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡HINDE, G. J., Ph.D., F.G.S. 11 Glebe-villas, Mitcham, Surrey.
1883. *Hindle, James Henry. 67 Avenue-parade, Accrington.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1881. §Hingston, J. T. Clifton, York.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *HIRST, T. ARCHER, Ph.D., F.R.S., F.R.A.S. 7 Oxford and Cambridge Mansions, Marylebone-road, London, N.W.
1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 29 Erskine-street, Liverpool.
*Hoare, Rev. Canon. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. The Dockyard, Chatham.

Year of
Election.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1879. §Hobkirk, Charles P., F.L.S. West Riding School, Huddersfield.
1883. §Hobson, Rev. E. W. 55 Albert-road, Southport.
1879. §Hobson, John. Tapton Elms, Sheffield.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. §Hocking, Rev. Silas R. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *HODGKIN, THOMAS. Benwell Dene, Newcastle-on-Tyne.
1880. §Hodgkinson, W. R. Eaton, Ph.D. Science Schools, South Kensington Museum, London, S.W.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1865. *HOFMANN, AUGUST WILHELM, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1883. §Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1883. §Holden, James. 12 Park-avenue, Southport.
1883. §Holden, John J. 23 Duke-street, Southport.
1879. ‡Holland, Calvert Bernard. Ashdell, Broomhill, Sheffield.
1878. *Holland, Rev. F. W., M.A. Evesham.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1865. ‡Holliday, William. New-street, Birmingham.
1883. §Hollingsworth, Dr. T. S. Elford Lodge, Spring-grove, Isleworth, Middlesex.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1876. ‡Holms, Colonel William, M.P. 95 Cromwell-road, South Kensington, London, S.W.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡HOOKER, Sir JOSEPH DALTON, K.C.S.I., K.C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew, Surrey.
1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Rev. Samuel F., M.A. 17 Lorrimore-square, London, S.E.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1882. *Hopkinson, Edward, D.Sc. 12 Queen Anne's-gate, London, S.W.
1870. *HOPKINSON, JOHN, M.A., D.Sc., F.R.S. 78 Holland-road, Kensington, London, W.
1871. *HOPKINSON, JOHN, F.L.S., F.G.S. 95 New Bond-street, London, W.; and Wansford House, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J. Surrey House, Forest Hill, London, S.E.

Year of Election.

1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
Houghton, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.G.S. Travellers' Club, London, S.W.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1879. *Howard, D. 60 Belsize Park, London, N.W.
1883. §Howard, James Fielden, M.D., M.R.C.S. Randycroft, Shaw.
1882. ‡Howard, William Frederick, Assoc. Memb. Inst. C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1883. §Howarth, Richard. York-road, Birkdale, Southport.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, H. H. Derby House, Eccles, Manchester.
1883. §Howorth, John, J.P. Springbank, Burnley, Lancashire.
1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.
1883. §Hoyle, James. Blackburn.
1883. §Hoyle, William. Claremont, Bury, Lancashire.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1879. ‡Hudson, Robert S., M.D. Redruth, Cornwall.
1883. §Hudson, Rev. W. C. 58 Belmont-street, Southport.
1867. ‡Hudson, William H. H., M.A., Professor of Mathematics in King's College, London. 14 Geraldine-road, Wandsworth, London, S.W.
1858. *Huggins, William, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse Hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
1883. §Hughes, Miss E. P. Newnham College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §Hughes, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡*Hughes, T. W. 4 Hawthorne-terrace, Newcastle-on-Tyne.*
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1883. §Hulke, John Whitaker, F.R.C.S., F.R.S., Pres. G.S. 10 Old Burlington-street, London, W.
1867. §Hull, Edward, M.A., LL.D., F.R.S., F.G.S., Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡Hume, Rev. Canon Abraham, D.C.L., LL.D., F.S.A. Vauxhall Vicarage, Liverpool.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *Humphry, George Murray, M.D., F.R.S., Professor of Surgery in the University of Cambridge. Grove Lodge, Cambridge.

Year of Election.

1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
1875. *Hunt, William. The Woodlands, Tyndall's Park, Clifton, Bristol.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1881. §Hunter, F. W. 4 Westmoreland-road, Newcastle-on-Tyne.
1881. ‡Hunter, Rev. John. 38 The Mount, York.
1869. *Hunter, Rev. Robert, LL.D., F.G.S. Forest Retreat, Staples-road, Loughton, Essex.
1879. §HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, London. King's College, London, W.C.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *Hurst, Charles Herbert. Owens College, Manchester.
1869. ‡Hurst, George. Bedford.
1882. §Hurst, Walter, B.Sc. 94 Lloyd-street, Greenheys, Manchester.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. May Bank, Bournemouth.
1882. ‡Hussey, Captain E. R., R.E. 24 Waterloo-place, Southampton.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1868. *Hutchison, Robert, F.R.S.E. 29 Chester-street, Edinburgh.
Hutton, Crompton. Putney Park, Surrey, S.W.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., Pres.R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1883. §Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
1879. ‡Ibbotson, H. J. 26 Collegiate-crescent, Sheffield.
Ihne, William, Ph.D. Heidelberg.
1873. ‡Ikin, J. I. 19 Park-place, Leeds.
1861. ‡Iles, The Ven. Archdeacon, M.A. The Close, Lichfield.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1876. ‡Inglis, Anthony. Broomhill, Partick, Glasgow.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice-General of Scotland. Edinburgh.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1883. §Ingram, Rev. D. C. Church-street, Southport.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Regius Professor of Greek in the University of Dublin. 2 Wellington-road, Dublin.
1882. §Irving, Rev. A., B.A., B.Sc., F.G.S. Wellington College, Wokingham, Berks.
1862. ‡ISELIN, J. F., M.A., F.G.S. South Kensington Museum, London, S.W.
1883. §Isherwood, James. 18 York-road, Birkdale, Southport.
1881. §Ishiguro, Isoji. The Sanitary Bureau of the Home Department, Tokio, Japan.

1865. ‡*Jabet, George. Wellington-road, Handsworth, Birmingham.*

Year of Election.

1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. §Jackson, A. H. New Bridge-street, Strangeways, Manchester.
1879. ‡Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1883. §Jackson, Mrs. Esther. 16 East Park-terrace, Southampton.
1883. §Jackson, Frank. 11 Park-crescent, Southport.
1883. *Jackson, F. J. Brooklands, Alderley Edge, Manchester.
1883. §Jackson, Mrs. F. J. Brooklands, Alderley Edge, Manchester.
1874. **Jackson, Frederick Arthur. Cheadle, Cheshire.*
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road, Lewisham, S.E.
1869. §Jackson, Moses. The Vale, Ramsgate.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, Surrey.
1874. *Jaffe, John. Edenvale, Strandtown, near Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1872. ‡James, Christopher. 8 Laurence Pountney-hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1863. *JAMES, Sir WALTER, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. Woodside, Plymouth.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1862. ‡*Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, London, W.*
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1856. §JEFFERY, HENRY M., M.A., F.R.S. 9 Dunstanville-terrace, Falmouth.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1883. §Jeffreys, Miss Gwyn. 1 The Terrace, Kensington, London, W.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. Pump-court, Temple, London, E.C.
1861. *JEFFREYS, J. GWYN, LL.D., F.R.S., F.L.S., F.G.S. 1 The Terrace, Kensington, London, W.
1852. ‡JELLETT, Rev. JOHN H., B.D., M.R.I.A., Provost of Trinity College, Dublin.
1881. §JELLICOE, C. W. A. Southampton.
1864. ‡Jelly, Dr. W. Madrid.
1862. §JENKIN, H. C. FLEEMING, F.R.S., M.Inst.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1873. §Jenkins, Major-General J. J. 14 St. James's-square, London, S.W.
1880. *JENKINS, Sir JOHN JONES, M.P. The Grange, Swansea.
Jennette, Matthew. 102A Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. Grand Hotel, Brighton.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
*Jerram, Rev. S. John, M.A. Chobham Vicarage, Woking Station, Surrey.

Year of Election.

1872. ‡Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square, London, W.

Jessop, William, jun. Butterley Hall, Derbyshire.

1883. §Johnson, Miss Alice. Llandaff House, Cambridge.

1883. §Johnson, Ben. Micklegate, York.

1871. *Johnson, David, F.C.S., F.G.S. Barrelwell House, Chester.

1881. ‡Johnson, Captain Edmond Cecil. Junior United Service Club, Charles-street, London, S.W.

1883. §Johnson, Edmund Litler. 73 Albert-road, Southport.

1854. Johnson, Edward. 22 Talbot-street, Southport.

1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.

1875. §Johnson, James Henry, F.G.S. 73 Albert-road, Southport.

1866. ‡Johnson, John G. 18A Basinghall-street, London, E.C.

1872. ‡Johnson, J. T. 27 Dale-street, Manchester.

1861. ‡Johnson, Richard. 27 Dale-street, Manchester.

1870. ‡Johnson, Richard C., F.R.A.S. 19 Catherine-street, Liverpool.

1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.

1881. §Johnson, Samuel George. Municipal Offices, Nottingham.

1883. §Johnson, W. H. T. Llandaff House, Cambridge.

1883. §Johnson, William. Harewood, Roe-lane, Southport.

1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.

1883. §Johnston, H. H. Tudor House, Champion Hill, London, S.E.

1859. ‡Johnston, James. Newmill, Elgin, N.B.

1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.

1883. §Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.

1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.

1864. ‡Johnstone, John. 1 Barnard-villas, Bath.

1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.

1864. ‡Jolly, Thomas. Park View-villas, Bath.

1871 ‡Jolly, William, F.R.S.E., F.G.S., H.M. Inspector of Schools. St. Andrew's-road, Pollokshields, Glasgow.

1881. ‡Jones, Alfred Orlando, M.D. Belton House, Harrogate.

1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.

1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.

1883. §Jones, George Oliver, M.A. 11 Cambridge-road, Waterloo, Liverpool.

1877. ‡*Jones, Henry C., F.C.S.* 166 *Blackstock-road, London, N.*

1883. §Jones, Rev. Canon Herbert. Waterloo, Liverpool.

1881. §Jones, J. Viriamu. University College of South Wales, Cardiff.

1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.

1880. §Jones, Thomas. 15 Gower-street, Swansea.

1860. ‡Jones, Thomas Rupert, F.R.S., F.G.S. 10 Uverdale-road, King's-road, Chelsea, London, S.W.

1883. §Jones, William. Elsinore, Birkdale, Southport.

1864. ‡Jones, Sir Willoughby, Bart., F.R.G.S. Cranmer Hall, Fakenham, Norfolk.

1875. *Jose, J. E. 3 Queen-square, Bristol.

*Joule, Benjamin St. John B., J.P. 12 Wardle-road, Sale, near Manchester.

1842. *Joule, James Prescott, LL.D., F.R.S., F.C.S. 12 Wardle-road, Sale, near Manchester.

1847. ‡Jowett, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.

1858. ‡Jowett, John. Leeds.

1879. ‡Jowitt, A. Hawthorn Lodge, Clarkehouse-road, Sheffield.

1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.

Year of Election.

1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.

Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.

1883. §Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.

1848. *Jubb, Abraham. Halifax.

1870. ‡JUDD, JOHN WESLEY, F.R.S., F.G.S., Professor of Geology in the Royal School of Mines. Hurstleigh, Kew.

1883. §Justice, Philip M. 14 Southampton-buildings, Chancery-lane, London, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 40 Finsbury-pavement, London, E.C.

KANE, Sir ROBERT, M.D., LL.D., F.R.S., M.R.I.A., F.C.S., Fortland, Killiney, Co. Dublin.

1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.

1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.

Kay, John Cunliff. Fairfield Hall, near Skipton.

Kay, Robert. Haugh Bank, Bolton-le-Moors.

1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.

1872. ‡*Keames, William M. 5 Lower Rock-gardens, Brighton.*

1883. §Kearne, John H. Westcliffe-road, Birkdale, Southport.

1875. ‡Keeling, George William. Tuthill, Lydney.

1881. ‡Keeping, Walter, M.A., F.G.S. The Museum, York.

1878. *Kelland, William Henry. 110 Jermyn-street, London, S.W.; and Grettans, Bow, North Devon.

1876. ‡Kelly, Andrew G. The Manse, Alloa, N.B.

1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.

1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.

1875. ‡KENNEDY, ALEXANDER B. W., M.Inst.C.E., Professor of Engineering in University College, London.

1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.

Kent, J. C. Levant Lodge, Earl's Croome, Worcester.

1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.

1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.

1855. *Ker, Robert. Dougalston, Milngavie, N.B.

1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.

1881. §Kermode, Philip M. C. Ramsay, Isle of Man.

1883. §Kerr, John. Garscadden, Bearsden, Glasgow.

1868. ‡Kerrison, Roger. Crown Bank, Norwich.

1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.

1869. *Kesselmeyer, William Johannes. Villa 'Mon Repos,' Altrincham, Cheshire.

1861. *Keymer, John. Parker-street, Manchester.

1883. *Keynes, J. N., M.A., B.Sc., F.S.S. Harvey-road, Cambridge.

1876. ‡Kidston, J. B. West Regent-street, Glasgow.

1876. ‡Kidston, William. Ferniegair, Helensburgh, N.B.

1865. *Kinahan, Edward Hudson, M.R.I.A. 11 Merrion-square North, Dublin.

1878. ‡Kinahan, Edward Hudson, jun. 11 Merrion-square North, Dublin.

1860. ‡KINAHAN, G. HENRY, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.

1875. *Kinch, Edward, F.C.S. Agricultural College, Cirencester.

1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne Park, London, W.

1875. *King, F. Ambrose. Avonside, Clifton, Bristol.

Year of Election.

1883. §King, Francis. Rose Bank, Penrith.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Welford House, Greenhill, Hampstead, London, N.W.
1870. §King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1883. *King, Joseph, jun. Welford House, Greenhill, Hampstead, London, N.W.
1864. §KING, KELBURNE, M.D. 27 George-street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. 1 Vittoria-square, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton, Bristol.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1883. §Kingston, Mrs. Sarah B. Boscastle House, Grove-road, Highgate-road, London, N.W.
1876. §Kingston, Thomas. Boscastle House, Grove-road, Highgate-road, London, N.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §KINGZETT, CHARLES T., F.C.S. 17 Lansdowne-road, Tottenham, Middlesex.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1867. *KINNAIRD, The Right Hon. Lord. 2 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1876. *Kirkwood, Anderson, LL.D., F.R.S.E. 7 Melville-terrace, Stirling, N.B.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1883. §Kirsop, Mrs. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1881. ‡Kitching, Langley. 50 Caledonian-road, Leeds.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. ‡*Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.*
1883. §Knight, J. R. 54 Stanhope-gardens, South Kensington, London, S.W.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1870. ‡Knowles, Rev. J. L. 103 Earl's Court-road, Kensington, London, W.
1842. *Knowles, John. The Lawn, Rugby.*
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1883. §Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. §Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B. 8 Belgrave-terrace, Hillhead, Glasgow.
*Knox, George James. 29 Portland-terrace, Regent's Park, London, N.W.

Year of
Election.
1835. *Knox, Thomas Perry. Union Club, Trafalgar-square, London, W.C.*
1875. *Knubley, Rev. E. P. Staveley Rectory, Leeds.
1883. §Knubley, Mrs. Staveley Rectory, Leeds.
1881. ‡Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.
1882. ‡Kyshe, John B. 19 Royal-avenue, Sloane-square, London, S.W.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1859. §Ladd, William, F.R.A.S. Claremont Villa, Rectory-road, Beckenham, Kent.
1870. ‡Laird, H. H. Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1882. ‡Lake, G. A. K., M.D. East Park-terrace, Southampton.
1880. ‡Lake, Samuel. Milford Docks, Milford Haven.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1883. §Lamb, W. J. 15 Weld-road, Birkdale, Southport.
1883. §Lambert, Rev. Brooke, LL.B. The Vicarage, Greenwich, Kent, S.E.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 8 The Circus, Greenwich, London, S.E.
1883. §Lang, Rev. Gavin. Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1864. ‡Lang, Robert. Langford Lodge, College-road, Clifton, Bristol.
1882. ‡Langstaff, Dr. Bassett, Southampton.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Docklands, Ingatestone, Essex.
1865. ‡LANKESTER, E. RAY, M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. 11 Wellington Mansions, North Bank, London, N.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.G.S. Eyre Cottage, Blackheath, London, S.E.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1881. ‡Larmor, Joseph, M.A., Professor of Natural Philosophy in Queen's College, Galway.
1883. §Lascelles, B. P. Dynevor Castle, Llandilo, South Wales.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡LAUGHTON, JOHN KNOX, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Greenwich, S.E.
1883. §Laurie, Major-General. Army and Navy Club, London, S.W.
1870. *Law, Channell. Sydney Villa, 36 Outram-road, Addiscombe, Croydon.
1878. ‡Law, Henry, C.E. 5 Queen Anne's-gate, London, S.W.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. §Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.

Year of
Election.

1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1868. *LAWSON, M. ALEXANDER, M.A., F.L.S. Botanic Gardens, Oxford.
1863. ‡*Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.*
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Colonel R. E. Mountjoy, Phœnix Park, Dublin.
1883. *Leach, Charles Catterall. Bedlington Colleries, Bedlington.
1883. §Leach, John. Haverhill House, Bolton.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1847. *LEATHAM, EDWARD ALDAM, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1844. *Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1858. ‡*Leather, John W. Newton-green, Leeds.*
1863. ‡Leavers, J. W. The Park, Nottingham.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1883. §Lee, Daniel W. 55 Fountain-street, Manchester.
1861. ‡Lee, Henry, M.P. Sedgeley Park, Manchester.
1883. §Lee, J. H. Warburton. Rossall, Fleetwood.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1882. ‡Lees, R. W. Moira-place, Southampton.
1883. *Leese, Miss H. R. Hazeldene, Fallowfield, Manchester.
*Leese, Joseph. Hazeldene, Fallowfield, Manchester.
1883. §Leese, Mrs. Hazeldene, Fallowfield, Manchester.
1881. §LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW, M.P., F.R.G.S. 18 Bryanston-square, London, W.
*LEFROY, Lieut.-General Sir JOHN HENRY, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S. 82 Queen's-gate, London, S.W.
*Legh, Lieutenant-Colonel George Cornwall. High Legh Hall, Cheshire.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1880. §Leighton, William Henry, F.G.S. 2 Merton-place, Chiswick.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E. 11 The Avenue, Southampton.
1863. *LENDY, Major AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, Sir John, C.B., M.D. Tallaght House, Co. Dublin; and 1 Great Denmark-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. ‡LEONARD, HUGH, F.G.S., M.R.I.A., F.R.G.S.I. St. David's, Malahide-road, Co. Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.

Year of
Election.

1872. ‡Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, M.Inst.C.E. 72 George-street, Edinburgh.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 5 Crown Office-row, Temple, London, E.C.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 35 Colebrooke-row, Islington, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, D.D., F.R.S., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
1883. §Lincoln, Frank. 111 Marylebone-road, London, N.W.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, C.E., F.G.S. 10 Kidbrooke-terrace, Blackheath, London, S.E.
*Lindsay, Charles. Ridge Park, Lanark, N.B.
1870. ‡Lindsay, Thomas, F.C.S. Maryfield College, Maryhill, by Glasgow.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
Lingwood, Robert M., M.A., F.L.S., F.G.S. 1 Derby-villas, Cheltenham.
1876. §Linn, James. Geological Survey Office, India-buildings, Edinburgh.
1883. §Lisle, H. Claud. Nantwich.
1882. *Lister, Rev. Henry, B.A. Hawridge Rectory, Berkhampstead.
1870. §Lister, Thomas. Victoria-crescent, Barnsley, Yorkshire.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Dublin.
Littledale, Harold. Liscard Hall, Cheshire.
1881. §Littlewood, Rev. B. C., M.A. Holmdale, Cheltenham.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.
1876. *Liversidge, Archibald, F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry and Mineralogy in the University of Sydney, N. S.W. (Care of Messrs. Trübner & Co., Ludgate Hill, London, E.C.)
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1880. ‡Llewelyn, John T. D. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Edgbaston-grove, Birmingham.
*Lloyd, George, M.D., F.G.S. Acock's-green, near Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1877. *Lloyd, Sampson Samuel. Moor Hall, Sutton Coldfield.
1865. *Lloyd, Wilson, F.R.G.S. Myrod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington Park, London, W.; and New Athenæum Club, S.W.
1853. *Locke, John. 133 Leinster-road, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. 16 Penywern-road, South Kensington, London, S.W.
1875. *LODGE, OLIVER J., D.Sc. 26 Waverley-road, Sefton Park, Liverpool.
1883. §Lofthouse, John. West Bank, Rochdale.

Year of Election.

1883. §London, Rev. H. High Lee, Knutsford.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. *Long, John Jex. 727 Duke-street, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. §Long, Mrs. Thelwall Heys, near Warrington.
1883. §Long, Miss. Thelwall Heys, near Warrington.
1866. §Longdon, Frederick. Osmaston-road, Derby.
1883. §Longe, Francis D. Coddenham Lodge, Cheltenham.
LONGFIELD, The Right Hon. MOUNTIFORT, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1883. §Longmaid, William Henry. 4 Rawlinson-road, Southport.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Butterknowle, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. §Longton, E. J., M.D. Lord-street, Southport.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1883. *Louis, D. A., F.C.S. Harpenden.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 2 Queensland-terrace, Oval-road, Croydon.
1883. §Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. J. 96 Lionel-street, Birmingham.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton, near Chepstow.
1870. ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.
1853. *LUBBOCK, Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. 34 Queen Anne's-gate, London, S.W.; and High Elms, Hayes, Kent.
1881. ‡Lubbock, John B. High Elms, Hayes, Kent.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.
1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1867. *Luis, John Henry. Cidhmore, Dundee.
1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1866. *Lund, Charles. 48 Market-street, Bradford, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. Teviot Bank, Newport Road, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Instructor in Coal Mining in Yorkshire College. 4 Albion Place, Leeds.

Year of Election.

1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton. The Harehills, near Leeds.
1874. *Lupton, Sydney, M.A. Harrow.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Leonard, F.G.S. 92 Onslow-gardens, London, S.W.
1874. ‡Lynam, James, C.E. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.
1878. ‡Lyte, Cecil Maxwell. Cotford, Oakhill-road, Putney, S.W.
1862. *LYTE, F. MAXWELL, F.C.S. Cotford, Oakhill-road, Putney, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *MACADAM, WILLIAM IVISON. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., F.R.S., Professor of Zoology in the University of Dublin. Trinity College, Dublin.
1878. §MACALISTER, DONALD, M.A., M.B., B.Sc. St. John's College, Cambridge.
1879. §MacAndrew, James J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S.W.
1838. Macaulay, Henry. 14 Clifton Bank, Rotherham, Yorkshire.
1840. MACAULAY, JAMES, A.M., M.D. 25 Carlton-road, Maida Vale, London, N.W.
1871. *MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1866. ‡M'CALLAN, Rev. J. F., M.A. Basford, near Nottingham.
1855. ‡M'Cann, Rev. James, D.D., F.G.S. 8 Oak-villas, Lower Norwood, Surrey, S.E.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'CLINTOCK, Rear-Admiral Sir FRANCIS L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *M'Clure, J. H., F.R.G.S. 5 Park-row, Albert-gate, London, S.W.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1859. *M'Connell, David C., F.G.S. Care of Mr. H. K. Lewis, 136 Gower-street, London, W.C.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1883. §McCrossan, James. 29 Albert-road, Southport.
1876. ‡M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1871. ‡*M'Donald, William. Yokohama, Japan.* (*Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.*)
1878. ‡McDonnell, Alexander. St. John's, Island Bridge, Dublin.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. §MacDonnell, Rev. Canon J. C., D.D. Maplewell, Loughborough.
1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1878. ‡McDonnell, Robert, M.D., F.R.S., M.R.I.A. Merrion-square, Dublin.
*M'Ewan, John. 4 Douglas-terrace, Stirling, N.B.
1881. ‡Macfarlane, A., D.Sc., F.R.S.E. The University, Edinburgh.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow.
1879. ‡Macfarlane, Walter, jun. 22 Park-circus, Glasgow.

Year of Election.

1854. *Macfie, Robert Andrew. Dreghorn, Colinton, Edinburgh.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡M'George, Mungo. Nithsdale, Laurie Park, Sydenham, S.E.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1855. ‡*MacGregor, James Watt. 2 Laurence-place, Partick, Glasgow.*
1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1874. ‡MacIlwaine, Rev. Canon, D.D., M.R.I.A. Ulsterville, Belfast.
1859. ‡*Macintosh, John. Middlefield House, Woodside, Aberdeen.*
1867. *M'Intosh, W. C., M.D., LL.D., F R.S. L. & E., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. 8 Abercromby-square, Liverpool.
1883. §Mack, Isaac A. Trinity-road, Bootle.
1871. ‡*Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.*
1873. ‡McKendrick, John G., M.D., F.R.S.E., Professor of the Institutes of Medicine in the University of Glasgow, and Fullerian Professor of Physiology in the Royal Institution, London.
1883. §McKendrick, Mrs. The University, Glasgow.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1883. §Mackeson, Henry. Hythe, Kent.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 1 Westbourne-terrace, Hyde Park, London, W.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, London, W.
*Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. 32 Glover-street, Birkenhead.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. West-view, Clarendon-road, Lewisham, S.E.
1873. ‡McLandsborough, John, M.Ins.C.E., F.R.A.S., F.G.S. South Park Villa, Harrogate, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. ‡MacLaren, Duncan. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1876. ‡*M'Lean, Charles. 6 Claremont-terrace, Glasgow.*
1876. ‡*M'Lean, Mrs. Charles. 6 Claremont-terrace, Glasgow.*
1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden Hill-road, London, W.
1868. §M'Leod, Herbert, F.R.S., F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William, F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Colonel C. A. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1883. §MacMahon, Captain P. A., R.A., Instructor in Mathematics at the Royal Military Academy, Woolwich.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.

Year of Election.

1871. ‡M'NAB, WILLIAM RAMSAY, M.D., Professor of Botany in the Royal College of Science, Dublin. 4 Vernon-parade, Clontarf, Dublin.
1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. §McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1883. §Macpherson, J. 44 Frederick-street, Edinburgh.
1852. *Macrory, Adam John. Duncairn, Belfast.
*MACRORY, EDMUND, M.A. 2 Ilchester-gardens, Prince's-square, London, W.
1876. *Mactear, James. 16 Burnbank-gardens, Glasgow.
1855. ‡MACVICAR, Rev. JOHN GIBSON, D.D., LL.D. Moffat, N.B.
1883. §McWhirter, William. 219 Argyll-street, Glasgow.
1883. §Madden, W. H. Cavendish College, Cambridge.
1883. §Maggs, Thomas Charles, F.G.S. Yeovil.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Philip. 48 Gloucester-place, Portman-square, London, W.
1879. ‡Mahomed, F. A., M.D. 12 St. Thomas-street, London, S.E.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. Admiralty, Whitehall, London, S.W.
1883. §Maitland, P. C. 233 East India-road, London, E.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1863. ‡*Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.*
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, U.S.
1846. ‡MANBY, CHARLES, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1866. §MANN, ROBERT JAMES, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, His Eminence Cardinal. Archbishop's House, Westminster, S.W.
1866. ‡*Manning, John. Waverley-street, Nottingham.*
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C. Whatcombe, Blandford.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1883. §Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.R.S., F.L.S., Sec.R.G.S., F.S.A. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
1881. *Marr, John Edward, B.A., F.G.S. St. John's College, Cambridge.
1871. ‡MARRECO, A. FRIERE-. College of Physical Science, Newcastle-on-Tyne.
1857. ‡Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1883. *Marsh, Henry. Crissy House, Wordsley-road, Leeds.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1882. *Marshall, A. Milnes, M.A., M.D., D.Sc., Professor of Zoology in Owens College, Manchester.
1881. ‡Marshall, D. H. Greenhill Cottage, Rothesay.
1881. *Marshall, John, F.R.A.S., F.G.S. Church Institute, Leeds.
1881. §Marshall, John Ingham Fearby. 28 St. Saviourgate, York.

Year of Election.

1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 15 Augustus-road, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1883. §Marten, Henry John. 4 Storey's-gate, London, S.W.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡Martin, Professor H. Newell. Baltimore, U.S.A.
1871. ‡*Martin, Rev. Hugh, M.A. Greenhill Cottage, Lasswade, by Edinburgh.*
1883. *Martin, John Biddulph, F.S.S. 68 Lombard-street, London, E.C.
1836. Martin, Studley. Liverpool.
*Martindale, Nicholas. Queen's Park, Chester.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1875. ‡Martyn, Samuel, M.D. 8 Buckingham-villas, Clifton, Bristol.
1883. §Marwick, James. Killermont, Maryhill, Glasgow.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., M.P., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. 39 Cornwall-gardens, London, W.
1861. *Mason, Hugh, M.P. Groby Hall, Ashton-under-Lyne.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)
1876. §Mason, Robert. 6 Albion-crescent, Dowanhill, Glasgow.
1876. ‡Mason, Stephen. 9 Rosslyn-terrace, Hillhead, Glasgow.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡*Massy, Frederick.* 50 *Grove-street, Liverpool.*
1883. §Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 60 Harborne-road, Birmingham.
1881. §Mathwin, Henry, B.A. Bickerton House, Southport.
1883. §Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1860. ‡Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. *Maxwell, Francis. Balgrove, North Berwick.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S., F.R.G.S. Northfield, St. Mary Cray, Kent.
1883. §Mayall, George. Clairville, Birkdale, Southport.
1868. ‡Mayall, J. E., F.C.S. Stork's Nest, Lancing, Sussex.
1835. Mayne, Edward Ellis. Rocklands, Stillorgan, Ireland.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1863. †*Mease, George D. Bylton Villa, South Shields.*
1883. §Medd, John Charles. 99 Park-street, Grosvenor-square, London, W.
1881. ‡Meek, Sir James. Middlethorpe, York.

Year of Election.

1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. Royal Victoria Yard, Deptford.
1881. *MELDOLA, RAPHAEL, F.R.A.S., F.C.S., F.I.C. 21 John-street, Bedford-row, London, W.C.
1867. ‡MELDRUM, CHARLES, M.A., F.R.S., F.R.A.S. Port Louis, Mauritius.
1883. §Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. St. Thomas's Rectory, Brampton, Chesterfield.
1883. §Mello, Mrs. J. M. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1881. ‡Melrose, James. Clifton, York.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General Count, LL.D. 35 Queen's-gate, London, S.W.
1862. ‡MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. ‡Merivale, John Herman, Professor of Mining in the College of Science, Newcastle-on-Tyne.
1879. ‡Merivale, Walter. Engineers' Office, North-Eastern Railway, Newcastle-on-Tyne.
1877. ‡Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Middlesbrough.
1883. §Middleton, Henry. St. John's College, Cambridge.
1881. §Middleton, R. Morton, F.L.S. Hudworth Cottage, Castle Eden, Co. Durham.
1876. *Middleton, Robert T., M.P. 197 West George-street, Glasgow.
1881. §MILES, MORRIS. Barron Villa, Hill, Southampton.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1863. ‡Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. ‡Millar, William. Highfield House, Dennistoun, Glasgow.
1876. ‡Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1882. §Miller, A. J. High-street, Southampton.
1876. ‡Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.
1861. *Miller, Robert. Cranage Hall, Holmes Chapel, Cheshire.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1876. ‡Miller, Thomas Paterson. Morriston House, Cambuslang, N.B.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S. 6 Craven-street, Strand, London, W.C.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's College, Glasgow. 60 John-street, Glasgow.
*Mills, John Robert. 11 Bootham, York.
1880. ‡Mills, Mansfeldt H. Tapton-grove, Chesterfield.

Year of Election.

Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. 13 New-street, Spring-gardens, London, S.W.

1882. *Milne, John, F.G.S., Professor of Geology in the Imperial College of Engineering, Tokio, Japan. 4 Bennett Park, Blackheath, London, S.E.

1867. *MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.

1882. §Milnes, Alfred, M.A., F.S.S. 30 Almeric-road, London, S.W.

1880. §Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.

1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.

1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.

1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.

1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.

1883. §Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, London, W.

1883. §Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, London, W.

1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.

1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.

1870. ‡Mitchell, John. Clough Bank, Clitheroe, Lancashire.

1868. ‡Mitchell, John, jun. Pole Park House, Dundee.

1862. **Mitchell, W. Stephen, M.A., LL.B. Caius College, Cambridge.*

1879. ‡MIVART, ST. GEORGE, M.D., F.R.S., F.L.S., F.Z.S., Professor of Biology in University College, Kensington. 71 Seymour-street, London, W.

1855. *Moffat, John, C.E. Ardrossan, Scotland.

1864. ‡Mogg, John Rees. High Littleton House, near Bristol.

1861. ‡MOLESWORTH, Rev. W. NASSAU, M.A. Spotland, Rochdale.

1883. §Mollison, W. L. Clare College, Cambridge.

1878. §Molloy, Constantine. 70 Lower Gardiner-street, Dublin.

1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.

1852. ‡*Molony, William, LL.D. Carrickfergus.*

1860. ‡Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.

1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.

1882. *Montagu, Samuel. 12 Kensington Palace-gardens, London, S.W.

1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.

1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.

1881. §Moore, Henry. 4 Sheffield-terrace, Kensington, London, W.

*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.

1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.

1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.

1877. ‡Moore, W. F. The Friary, Plymouth.

1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.

1877. ‡Moore, William Vanderkemp. 15 Princess-square, Plymouth.

1871. ‡MORE, ALEXANDER G., F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.

1881. §MORGAN, ALFRED. 3 Aughton-road, Birkdale, Lancashire.

1873. ‡Morgan, Edward Delmar. 15 Rowland-gardens, London, W.

1882. §Morgan, Thomas. Cross House, Southampton.

1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.

1878. ‡MORGAN, WILLIAM, Ph.D., F.C.S. Swansea.

Year of Election.

1867. ‡Morison, William R. Dundee.
1883. §Morley, Henry Forster, M.A., B.Sc., F.C.S. University Hall, Gordon-square, London, W.C.
1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, London, E.C.
1881. §Morrell, W. W. York City and County Bank, York.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
1883. §Morris, C. S. Millbrook Iron Works, Landore, South Wales.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
1883. §Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. ‡Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. §Morris, John. 40 Wellesley-road, Liverpool.
1881. ‡Morris, John, M.A., F.G.S., Emeritus Professor of Geology in University College, London. 4 Vinery-villas, Park-road, London, N.W.
1880. ‡Morris, M. I. E. The Lodge, Penclawdd, near Swansea.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. ‡Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1879. ‡*Morrison, Dr. R. Milner. 20 Pentland-terrace, Edinburgh.*
1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 122 London-road, Liverpool.
1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1868. ‡Moseley, H. N., M.A., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 14 St. Giles', Oxford.
1883. §Moseley, Mrs. 14 St. Giles', Oxford.
1857. ‡*Moses, Marcus. 4 Westmoreland-street, Dublin.*
1868. Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1878. *Moss, JOHN FRANCIS. Ranmoor, Sheffield.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. 66 Kenilworth-square, Rathgar, Dublin.
1873. *Mosse, George Staley. 2 Albany-villas, Queen's-road, Twickenham.
1874. *Mosse, J. R. Conservative Club, London, S.W.
1873. †Mossman, William. Woodhall, Calverley, Leeds.
1869. §MOTT, ALBERT J., F.G.S. Crickley Hill, Gloucester.
1865. ‡Mott, Charles Grey. The Park, Birkenhead.
1866. §MOTT, FREDERICK T., F.R.G.S. Birstall Hill, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. Fletcher, M.A., F.R.S. 74 Onslow-gardens, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.

Year of Election.

1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡Mount-Edgcumbe, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1882. ‡Mount-Temple, The Right Hon. Lord. Broadlands, Romsey, Hants.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, M.A. F.R.S.E. Caius College, Cambridge.
1876. §Muir, Thomas. High School, Glasgow.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 29 Regency-street, Westminster, S.W.
1871. *Muirhead, Henry, M.D. Bushy Hill, Cambuslang, Lanarkshire.
1876. *Muirhead, Robert Franklin, B.Sc. Meikle Cloak, Lochwinnoch, Renfrewshire.
1883. §Mulhall, Michael G. 19 Albion-street, Hyde-park, London, W.
1883. §Mulhall, Mrs. Marion. 19 Albion-street, Hyde-park, London, W.
1880. §Muller, Hugo M. 1 Grunangergasse, Vienna.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡Mundella, The Right Hon. A. J., M.P., F.R.S., F.R.G.S. The Park, Nottingham.
1883. ‡Munro, Donald, F.C.S. The University, Glasgow.
1883. *Munro, Robert. Braehead House, Kilmarnock, N.B.
1872. *Munster, H. Sillwood Lodge, Brighton.
1864. ‡Murch, Jerom. Cranwells, Bath.
*_Murchison, John Henry. Surbiton Hill, Kingston._
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1876. ‡_Murdoch, James. Altony Albany, Girvan, N.B._
1855. ‡Murdoch, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. ‡Murray, Adam. Westbourne Sussex-gardens, Hyde-park, London, W.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, M.Inst.C.E. Downlands, Sutton, Surrey.
1863. ‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1883. §Murray, W. Vaughan. 4 Westbourne-crescent, Hyde Park, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1859. ‡Mylne, Robert William, F.R.S., F.G.S., F.S.A. 2 Middle Scotland-yard, London, S.W.

1842. Nadin, Joseph. Manchester.
1876. §Napier, James S. 9 Woodside-place, Glasgow.
1876. ‡Napier, John. Saughfield House, Hillhead, Glasgow.
*Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1872. ‡Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 23 St. Philip's-road, Surbiton.

Year of Election.

1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1883. §Neild, Theodore. Dalton Hall, Manchester.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.
Neilson, Robert, J.P., D.L. Halewood. Liverpool.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1876. ‡Nelson, D. M. 48 Gordon-street, Glasgow.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡NEVILLE, PARKE, M.Inst.C.E., M.R.I.A. 58 Pembroke-road, Dublin.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare Hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F.R.S., F.R.A.S. Ferndene, Gateshead-upon-Tyne.
1879. ‡Newbould, John. Sharrow Bank, Sheffield.
1866. *Newdigate, Albert L. 25 Craven-street, Charing Cross, London, W.C.
1876. ‡Newhaus, Albert. 1 Prince's-terrace, Glasgow.
1883. §Newman, Albert Robert. 20 Northumberland-street, Marylebone, London, W.
1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.
1883. §Newton, A. W. 7a Westcliffe-road, Birkdale, Southport.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1883. §Nias, Miss Isabel. Girton College, Cambridge.
1882. ‡Nias, J. B., B.A. 56 Montagu-square, London, W.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Ashleigh, Ventnor, Isle of Wight.
1861. *Nicholson, Edward. Beech Hill, Londonderry.
1871. §Nicholson, E. Chambers. Herne Hill, London, S.E.
1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.
1883. §Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1881. §Nicholson, William R. Clifton, York.
1867. ‡Nimmo, Dr. Matthew. Nethergate, Dundee.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. Aberdeen.
1877. ‡Niven, James, M.A. King's College, Aberdeen.
‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1863. *NOBLE, Captain ANDREW, F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-on-Tyne.
1880. ‡Noble, John. Rossenstein, Thornhill-road, Croydon, Surrey.
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1882. §Norfolk, F. Fitzhugh's Park, Southampton.

Year of Election.

1859. ‡Norfolk, Richard. Ladygate, Beverley.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §Norman, Rev. Alfred Merle, M.A., D.C.L., F.L.S. Burnmoor Rectory, Fence House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡Norris Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William, G. Coalbrookdale, Shropshire.
1881. §North, Samuel William, M.R.C.S., F.G.S. 84 Micklegate, York.
1881. ‡North, William, B.A., F.C.S. 34 Bernard-street, Russell-square, London, W.C.
1869. ‡Northcote, The Right Hon. Sir Stafford H., Bart., G.C.B., M.P., F.R.S. Pynes, Exeter.
*Northwick, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
Norton, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1878. ‡Nugent, Edward. Seel's-buildings, Liverpool.
1883. §Nunnerley, John. 46 Alexandra-road, Southport.
1883. §Nutt, Alfred. Rosendale Hall, West Dulwich, London, S.E.
1883. §Nutt, Miss Lilian. Rosendale Hall, West Dulwich, London, S.E.
1883. §Nutt, Miss Mabel. Rosendale Hall, West Dulwich, London, S.E.

1882. §Obach, Eugene, Ph.D. 17 Charlton-villas, Old Charlton, Kent.
1878. ‡O'Brien, Murrough. 1 Willow-terrace, Blackrock, Co. Dublin.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Carroll, Joseph F. 78 Rathgar-road, Dublin.
1878. ‡O'Conor Don, The, M.P. Clonalis, Castlerea, Ireland.
1883. §Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, London, E.C.
Odgers, Rev. William James. Savile House, Fitzjohn's-avenue, Hampstead, London, N.W.
1858. *Odling, William, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. §Ogden, Joseph. 46 London-wall, London, E.C.
1876. ‡Ogilvie, Campbell P. Sizewell House, Lenton, Suffolk.
1874. ‡Ogilvie, Thomas Robertson. Bank Top, 3 Lyle-street, Greenock, N.B.
*Ogilvie-Forbes, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. Boyndlie, Fraserburgh, N.B.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldovan House, Dundee.
1863. ‡Ogilvy, Sir John, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John, M.A., Q.C. 22 Upper Fitzwilliam-street, Dublin.
1874. ‡O'Hagan, The Right Hon. Lord, M.R.I.A. 34 Rutland-square West, Dublin.
1881. ‡Oldfield, Joseph. Lendal, York.
1853. §Oldham, James, M.Inst.C.E. Cottingham, near Hull.

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1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
1883. §Oliver, J. A. Westwood. 13 Hogarth-road, South Kensington, London, S.W.
1883. §Oliver, Samuel A. Springfield, Wigan, Lancashire.
1882. §Olsen, O. T., F.R.A S., F.R.G.S. 3 St. Andrew's-terrace, Grimsby.
*OMMANNEY, Admiral Sir ERASMUS, C.B., F.R.S., F.R.A.S., F.R.G.S. The Towers, Yarmouth, Isle of Wight.
1880. *Ommanney, Commander E. A., R.N. 44 Charing Cross, London, W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1883. §Oppert, Gustav, Professor of Sanskrit. Madras.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. §Ord, Miss Maria. 13 Park-crescent, Southport.
1883. §Ord, Miss Sarah. 13 Park-crescent, Southport.
1880. ‡O'Reilly, J. P. Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Woodway, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1835. ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1883. §Orpen, Miss. 58 Stephen's-green, Dublin.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1873. ‡Osborn, George. 47 Kingscross-street, Halifax.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1877. *Osler, Miss A. F. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. Chesham Lodge, Lower Norwood, Surrey.
1882. *Oswald, T. R. New Place House, Southampton.
1881. *Ottewell, Alfred D. 83 Siddals-road, Derby.
1854. ‡Outram, Thomas. Greetland, near Halifax.
1883. *Ovenden, Frederick H. 93 and 95 City-road, London, E.C.
1882. ‡Owen, Rev. C. M., M.A. Woolston Vicarage, Southampton.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡*Owen, James H. Park House, Sandymount, Co. Dublin.*
OWEN, Sir RICHARD, K.C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. Sheen Lodge, Mortlake, Surrey, S.W.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1883. §Page, George, W. Fakenham, Norfolk.
1883. §Page, Joseph Edward. 12 Saunders-street, Southport.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *PALGRAVE, R. H. INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.
1883. §Palgrave. Mrs. R. H. Inglis. Belton, Great Yarmouth.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1878. *Palmer, Joseph Edward. Lyons Mills, Straffan Station, Dublin.
1866. §Palmer, William. Kilbourne House, Cavendish Hill, Sherwood, Notts.
1872. **Palmer, W. R. Hawthorne, Rivercourt-road, Hammersmith, W.*
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1883. §Pant, F. J. van der. Clifton Lodge, Kingston on Thames.
1883. §Park, Henry. Wigan.

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1883. §Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. Barrow-in-Furness, Lancashire.
1857. *Parker, Alexander, M.R.I.A. 59 William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Richard. Dunscombe, Cork.
1865. *Parker, Walter Mantel. High-street, Alton, Hants.
Parker, Rev. William. Saham, Norfolk.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling, F.L.S. 6 St. Mary's-row, Birmingham.
1864. ‡Parkes, William. 23 Abingdon-street, Westminster, S.W.
1879. §Parkin, William, F.S.S. The Mount, Sheffield.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1841. Parnell, Edward A., F.C.S. Ashley Villa, Swansea.
1862. *Parnell, John, M.A. 1 The Common, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1883. §Parson, T. Cooke, M.R.C.S. Atherston House, Clifton.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. 10 Connaught-place, London, W.
1878. ‡Parsons, Hon. and Rev. R. C. 10 Connaught-place, London, W.
1883. §Part, C. T. 5 King's Bench-walk, Temple, London, E.C.
1883. §Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. §Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1883. §Paton, Henry. 15 Myrtle-terrace, Edinburgh.
1883. §Paton, Rev. William. Mossfield House, New Ferry, Chester.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1876. §Patterson, T. L. Belmont, Margaret-street, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡Pattinson, John, F.C.S. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡Paul, Benjamin H., Ph.D. 1 Victoria-street, Westminster, S.W.
1883. §Paul, G., F.G.S. Moortown, Leeds.
1863. ‡Pavy, Frederick William, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-on-Tyne.
1877. *Payne, J. C. Charles. Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1876. ‡Peace, G. H. Morton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Western Bank, Sheffield.

Year of Election.

1847. ‡PEACH, CHARLES W., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1883. §Peacock, Ebenezer. 8 Harley-street, London, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *PEARCE, HORACE, F.L.S., F.G.S. The Limes, Stourbridge.
1882. §Pearce, Walter, B.Sc., F.C.S. Craufurd, Ray Mead, Maidenhead.
1876. ‡Pearce, W. Elmpark House, Govan, Glasgow.
*Pearsall, Thomas John. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W.C.
1881. ‡Pearse, Richard Seward. Southampton.
1883. §Pearson, Arthur A. Colonial Office, London, S.W.
1883. §Pearson, Miss Helen, E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. §Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Lern Side Works, Nottingham.
1881. ‡Pearson, Richard. 23 Bootham, York.
1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.
1883. *Pearson, Thomas H. Golborne Park, near Newton-le-Willows, Lancashire.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1883. §Peck, John Henry. 52 Hoghton-street, Southport.
1883. §Peek, C. E. Conservative Club, London, S.W.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1878. *Peek, William. St. Clair, Hayward's Heath, Sussex.
*Peel, George. Soho Iron Works, Manchester.
1873. ‡Peel, Thomas. 9 Hampton-place, Bradford, Yorkshire.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.
1868. †*Pendergast, Thomas. Lancefield, Cheltenham.*
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Percival, Rev. John, M.A., LL.D., President of Trinity College, Oxford.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.
1868. *PERKIN, WILLIAM HENRY, F.R.S , F.C.S. The Chestnuts, Sudbury, Harrow.
1877. ‡Perkins, Loftus. 140 Abbey-road, Kilburn, London, N.W.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1879. ‡Perry, James. Roscommon.
1874. *PERRY, JOHN. 10 Penywern-road, South Kensington, London, S.W.

Year of
Election

1883. §Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. §Perry, Russell R. 34 Duke-street, Brighton.
1870. *PERRY, Rev. S. J., F.R.S., F.R.A.S., F.R.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1883. §Petrie, Miss Anne S. Stone Hill, Rochdale.
1883. §Petrie, Miss Isabella. Stone Hill, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 108 Marina, St. Leonard's-on-Sea.
1882. ‡Pfoundes, Charles, F.R.G.S. Spring Gardens, London, S.W.
1867. ‡PHAYRE, Lieut.-General Sir ARTHUR, K.C.S.I., C.B. Athenæum Club, Pall Mall, London, S.W.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
Philips, Robert N., M.P. The Park, Manchester.
1877. §Philips, T. Wishart. 33 Woodstock-road, Poplar, London, E.
1863. ‡Philipson, Dr. 1 Savile-row, Newcastle-on-Tyne.
1883. §Phillips, Arthur G. 20 Canning-street, Liverpool.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1872. ‡PHILLIPS, J. ARTHUR, F.R.S., F.G.S., F.C.S. 18 Fopstone-road, Earl's Court-road, London, S.W.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1883. §Phillips, Mrs. Leah R. 1 East Park-terrace, Southampton.
1883. §Phillips, S. Rees. Wanford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1883. *Pickard, Joseph William. Oak Bank, Lancaster.
1864. ‡Pickering, William. Oak View, Clevedon.
1870. ‡Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
*Pike, Ebenezer. Besborough, Cork.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, London, W.
1873. ‡Pike, W. H. 4 The Grove, Highgate, London, N.
1857. ‡Pilkington, Henry M., LL.D., Q.C. 45 Upper Mount-street, Dublin.
1883. §Pilling, R. C. The Robin's Nest, Blackburn.
1863. *PIM, Captain BEDFORD C. T., R.N., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡Pirie, Rev. G. Queen's College, Cambridge.
1859. ‡Pirrie, William, M.D., LL.D. 238 Union-street West, Aberdeen.
1866. ‡*Pitcairn, David. Dudhope House, Dundee.*
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. §Pitt, George Newton. Sutton, Surrey.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. §Pitt, Sydney. Sutton, Surrey.
1868. ‡PITT-RIVERS, Major-General A. H. L., F.R.S., F.G.S., F.R.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.

Year of
Election.

1872. ‡Plant, Mrs. H. W. 28 Evington-street, Leicester.
1869. §Plant, James, F.G.S. 40 West-terrace, West-street, Leicester.
1842. Playfair, The Right Hon. Sir Lyon, K.C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡Playfair, Lieut.-Colonel R. L., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1883. *Plimpton, Henry G., M.D. 23 Lansdowne-road, Clapham-road, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *Pochin, Henry Davis, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1846. ‡Pole, William, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Portal, Wyndham S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. Kensington House, Southport.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D., President of Queen's College, Belfast.
1866. §Porter, Robert. Montpelier Cottage, Beeston, Nottingham.
1883. §Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
1883. §Potter, M. C., B.A. St. Peter's College, Cambridge.
Potter, Richard, M.A. 10 Brookside, Cambridge.
1883. §Potts, John. 33 Chester-road, Macclesfield.
1857. *Pounden, Captain Lonsdale, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1883. §Powell, John. Wannarlwydd House, near Swansea.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1883. §Poynting, J. H. Brentwood, Hagley-road, Edgbaston, Birmingham.
1869. *Preece, William Henry, F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
Prest, The Venerable Archdeacon Edward. The College, Durham.
1881. §Preston, Rev. Thomas Arthur, M.A. The Green, Marlborough.
*Prestwich, Joseph, M.A., F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 35 St. Giles', Oxford; and Shoreham, near Sevenoaks.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-fields, London, W.C.
1856. *Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford, 11 St. Giles's, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
1882. ‡Price, John E., F.S.A. 60 Albion-road, Stoke Newington, London, N.
Price, J. T. Neath Abbey, Glamorganshire.
1881. §Price, Peter. Crockherbtown, Cardiff.

Year of Election.

1875. *Price, Rees. 1 Montague-place, Glasgow.
1870. *Price, Major W. E., F.G.S. Hillfield, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. ‡Priestley, John. 174 Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1883. §Prince, Thomas. Horsham-road, Dorking.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1881. §Procter, John William. Ashcroft, Nunthorpe, York.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1863. *Prosser, Thomas. 25 Harrison-place, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. 4 Cambridge-villas, Richmond Park-road, Kingston-on-Thames.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Tayside, Perth.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
Punnet, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. §Purrott, Charles. West End, near Southampton.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883. §Pye-Smith, Arnold. 16 Fairfield-road, Croydon.
1883. §Pye-Smith, Mrs. 16 Fairfield-road, Croydon.
1868. §PYE-SMITH, P. H., M.D. 54 Harley-street, W.; and Guy's Hospital, London, S.E.
1879. §Pye-Smith, R. J. 6 Surrey-street, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1870. ‡Rabbits, W. T. Forest Hill, London, S.E.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡Radford, R. Heber. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, Lord. 70 Portland-place, London, W.
1878. ‡Rae, John, M.D., LL.D., F.R.S. 2 Addison-gardens South, Kensington, London, W.
1854. †Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.

Year of Election.

1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡Ramsay, Alexander, F.G.S. 2 Cowper-road, Acton, Middlesex, W.
1845. ‡Ramsay, Sir Andrew Crombie, LL.D., F.R.S., F.G.S. 15 Cromwell-crescent, South Kensington, London, S.W.
1861. ‡Ramsay, John, M.P. Kildalton, Argyleshire.
1883. §Ramsay, Mrs. 10 Osborne-road, Clifton, Bristol.
1867. *Ramsay, W. F., M.D. 39 Hammersmith-road, West Kensington, London, W.
1876. ‡Ramsay, William, Ph.D., Professor of Chemistry in University College, Bristol.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry. St. Andrew's-street, Cambridge.
1869. *Rance, H. W. Henniker, LL.M. 10 Castletown-road, West Kensington, London, S.W.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1868. *Ransom, Edwin, F.R.G.S. The Oval, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1858. *Ratcliff, Colonel Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. 26 Lancaster-gate, Hyde Park, London, S.W.
1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
1874. ‡Ravenstein, E. G., F.R.G.S. 29 Lambert-road, Brixton, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhall, Liverpool.
1866. *Rawlinson, Rev. Canon George, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1875. §Rawson, Sir Rawson W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1883. §Ray, Miss Catherine. Care of W. Freuer, Esq., West Rudham, Swaffham, Norfolk.
1868. *Rayleigh, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. (President Elect.) 5 Salisbury-villas, Cambridge.
1883. §Rayne, Charles A., M.B., B.Sc., M.R.C.S. 3 Queen-street, Lancaster.
1865. ‡Read, William. Albion House, Epworth, Rawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. §Reade, Thomas Mellard, F.G.S. Blundellsands, Liverpool.

Year of
Election.

1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 5 Crowhurst-road, Brixton, London, S.W.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡*Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.*
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡REED, Sir EDWARD J., K.C.B., M.P., F.R.S. 74 Gloucester-road, South Kensington, London, W.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1878. §Reichel, The Ven. Archdeacon, D.D. The Archdeaconry, Trim, Ireland.
1881. §Reid, Arthur S., B.A., F.G.S. 12 Bridge-street, Canterbury.
1883. *Reid, Clement. Burnham, Lynn.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1881. ‡Reid, William. 19½ Blake-street, York.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physical Science. Royal Naval College, Greenwich, S.E.
1863. §RENALS, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. 12 Leicester-street, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.A., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., F.R.S., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. 13 Briggate, Leeds.
1883. §Rhodes, Dr. James. 25 Victoria-street, Glossop.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1863. ‡RICHARDSON, BENJAMIN WARD, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 4 Northumberland-avenue, Putney, S.W.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡*Richardson, J. H. 3 Arundel-terrace, Cork.*
1870. ‡Richardson, Ralph, F.R.S.E. 19 Castle-street, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
1881. ‡Richardson, W. B. Elm Bank, York.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1863. ‡*Richter, Otto, Ph.D. 6 Derby-terrace, Glasgow.*
1868. §RICKETTS, CHARLES, M.D., F.G.S. 22 Argyle-street, Birkenhead.
1877. ‡Ricketts, James, M.D. St. Helen's, Lancashire.
1883. *Rideal, Samuel. Mayow-road, Forest-hill, Kent, S.E.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury Morpeth.
1872. ‡Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.

Year of
Election.

1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. *Rigby, Samuel. Fern Bank, Liverpool-road, Chester.
1881. *Rigg, Arthur. 79 Warrington-crescent, London, W.
1883. §Rigg, Edward, M.A. Royal Mint, London, E.
1883. §Rigg, F. F., M.A. 32 Queen's-road, Southport.
1883. §Rigge, Samuel Taylor. Halifax.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*Ripon, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. Babbicombe, near Torquay.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *Robbins, John, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1859. ‡Roberts, George Christopher. Hull.
1870. *Roberts, Isaac, F.G.S. Kennessee, Maghull, Lancashire.
1881. §Roberts, R. D., M.A., D.Sc., F.G.S. Clare College, Cambridge.
1883. §Roberts, Ralph A. 23 Clyde-road, Dublin.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1883. §Roberts, William, M.D. 89 Moseley-street, Manchester.
1868. ‡Roberts, W. Chandler, F.R.S., F.G.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal School of Mines. Royal Mint, London, E.
1883. §Robertson, Alexander. Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1871. ‡Robertson, George, M.Inst.C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1883. §Robertson, George H. The Nook, Gateacre, near Liverpool.
1883. §Robertson, Mrs. George H. The Nook, Gateacre, near Liverpool.
1870. *Robertson, John. 4 Albert-road, Southport.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1866. ‡Robertson, William Tindal, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Beech Hill, Armagh.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
*Robinson, H. Oliver. 34 Bishopsgate-street, London, E.C.
1873. §Robinson, Hugh. 82 Donegall-street, Belfast.
1861. ‡Robinson, John, M.Inst.C.E. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1881. §Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, M.Inst.C.E., F.G.S. 2 West-terrace, Darlington.
1860. ‡Robinson Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1882. §Robinson, W. Braham. Rosenheim, The Avenue, Southampton.
1870. *Robson, E. R. 41 Parliament-street, Westminster, S.W.
1876. ‡Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
1855. ‡Robson, Neil. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.

Year of Election.

1872. §RODWELL, GEORGE F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1860. ‡ROGERS, JAMES E. THOROLD, M.P., Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1869. *Rogers, Nathaniel, M.D. 87 South-street, Exeter.
1883. §Rogers, Captain R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1883. §Rogers, Thomas Stanley, LL.B. 77 Albert-road, Southport.
1876. §ROLLIT, A. K., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1876. ‡Romanes, George John, M.A., F.R.S., F.L.S. 18 Cornwall-terrace, Regent's Park, London, N.W.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. ‡Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. *Roper, W. O. Southfield, Lancaster.
1855. *ROSCOE, HENRY ENFIELD, B.A., Ph.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1883. *Rose, Rev. J. Holland. The College, Ventnor, Isle of Wight.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. 32 Nelson-street, Dublin.
1880. §Ross, Captain G. E. A., F.R.G.S. Forfar House, Cromwell-road, London, S.W.
1872. ‡Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1874. ‡Ross, Rev. William. Chapelhill Manse, Rothesay, Scotland.
1880. ‡Ross, Colonel William Alexander. Acton House, Acton, London, W.
1869. *ROSSE, The Right Hon. the Earl of, B.A., D.C.L., LL.D., F.R.S. F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1861. ‡Routh, Edward J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1881. ‡Routh, Rev. William, M.A. Clifton Green, York.
1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. §Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.
1877. §ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1881. *ROWE, R. C., M.A. Trinity College, Cambridge.
1855. *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry, in Queen's College, Galway. Salerno, Salthill, Galway.
1881. *Rowntree, Joseph. 24 St. Mary's, York.
1881. *ROWNTREE, J. S. The Mount, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1883. §Roy, Charles S. Brown Institution, Wandsworth-road, London, S.W.

Year of
Election.

1861. *Royle, Peter, M.D., L.R.C.P., M.R.C S. 27 Lever-street, Manchester.
1875. ‡Rücker, A. W., M.A., Professor of Mathematics and Physics in the Yorkshire College, Leeds.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Queen Anne's-gate, London, S.W.
1873. ‡*Rushforth, Joseph. 43 Ash-grove, Horton-lane, Bradford, Yorkshire.*
1847. ‡Ruskin, John, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Brantwood, Coniston, Ambleside.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1876. *Russell, George. 103 Blenheim-crescent, Notting Hill, London, W.
1883. §Russell, J. W. Merton College, Oxford.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
Russell, John. 39 Mountjoy-square, Dublin.
1876. §Russell, R., F.G.S. 1 Sea View, St. Bees, Carnforth.
1862. §Russell, W. H. L., B.A., F.R.S. 3 Ridgmount-terrace, Highgate, London, N.
1852. *Russell, William J., Ph.D., F.R.S., F.C.S., Professor of Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1883. *Ruston, Joseph. Monk's Manor, Lincoln.
1871. §Rutherford, William, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
1881. ‡Rutson, Albert. Newby Wiske, Thirsk.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1879. ‡Ruxton, Captain Fitzherbert, R.N. 41 Cromwell-gardens, London, S.W.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1874. ‡Rye, E. C., F.Z.S., Librarian R.G.S. Royal Geographical Society, 1 Savile-row, London, W.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. *Sabine, Robert. 3 Great Winchester-street-buildings. London, E.C.
1883. §Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1880. ‡*Sakurai, J. 96 Camden-street, London, N.W.*
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡Salmon, Rev. George, D.D., D.C.L., LL.D., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1883. §Salmond, Robert G. The Nook, Kingswood-road, Upper-Norwood, S.E.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1883. §Salt, Shirley H. Maplewell, near Loughborough.
1872. ‡Salvin, Osbert, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1861. *Sandeman, Archibald, M.A. Garry Cottage, Perth.
1876. ‡Sandeman, David. Woodlands, Lenzie, Glasgow.
1883. §Sandeman, E. 53 Newton-street, Greenock.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.

Year of Election.

1883. §Sanders, Charles J. B. Pennsylvania, Exeter.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.
1883. §Sanderson, Surgeon Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. ‡SANDERSON, J. S. BURDON, M.D., LL.D., F.R.S., Professor of Physiology in the University of Oxford. 50 Banbury-road, Oxford.
1883. §Sanderson, Mrs. Burdon. 50 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1873. ‡Sands, T. C. 24 Spring-gardens, Bradford, Yorkshire.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1881. §SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1883. §Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1883. §Savage, W. W. 109 St. James's-street, Brighton.
1883. §Savery, G. M., M.A. Cotlake House, Taunton.
1872. *Sawyer, George David, F.R.M.S. 55 Buckingham-place, Brighton.
1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1883. *Scarborough, George. Holly Bank, Halifax, Yorkshire.
1883. §Scarisbrick, Charles. 5 Palace-gate, Kensington, London, W.
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
1879. *Schäfer, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. Boreham Wood, Elstree, Herts.
1883. §Schafer, Mrs. Boreham Wood, Elstree, Herts.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1883. §Schofield, William. Alma-road, Birkdale, Southport.
1874. §Scholefield, Henry. Windsor-crescent, Newcastle-on-Tyne.
1876. ‡Schuman, Sigismond. 7 Royal Bank-place, Glasgow.
SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Applied Mathematics in Owens College, Manchester.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec. Zool. Soc. 11 Hanover-square, London, W.
1883. *Sclater, William Lutley. Keble College, Oxford.
1882. *SCLATER-BOOTH, The Right Hon. G., M.P., F.R.S. 74 St. George's-square, London, S.W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., B.Sc. Trinity College, Cambridge.
1882. §Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. ‡Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. §Scott, Miss Charlotte Angus. Girton College, Cambridge.
1876. ‡Scott, Mr. Bailie. Glasgow.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.R.M.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.

Year of
Election.

1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1874. ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1881. *Scrivener, A. P. Weston Turvill, Tring.
1883. §Scrivener, Mrs. Weston Turvill, Tring.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡Sedgwick, Adam, B.A. Trinity College, Cambridge.
1880. ‡Seebohm, Henry, F.L.S., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1861. *Seeley, Harry Govier, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. The Vine, Sevenoaks.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. §Selim, Adolphus. 21 Mincing-lane, London, E.C.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1858. *Senior, George, F.S.S. Rosehill, Dodworth, near Barnsley.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1883. §Seville, Miss. Blythe House, Southport.
1875. §Seville, Thomas. Blythe House, Southport.
1873. ‡Sewell, Rev. E., M.A., F.G.S., F.R.G.S. Ilkley College, near Leeds
1868. ‡Sewell, Philip E. Catton, Norwich.
1883. §Shadwell, John Lancelot. 21 Nottingham-place, London, W.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871. *Shand, James. Fullbrooks, Worcester Park, Surrey.
1867. §Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡Sharp, David, M.B. Thornhill, Dumfriesshire.
Sharp, Rev. John, B.A. Horbury, Wakefield.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1883. §Sharples, Charles H., F.C.S. 7 Fishergate, Preston.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1881. *Shaw, H. S. Hele, Professor of Engineering in University College, Bristol. 7 Vyvyan-terrace, Clifton, Bristol.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1883. *Shaw, W. N., M.A. Emmanuel College, Cambridge.
1883. §Sheard, J. 42 Hoghton-street, Southport.
1883. §Shearer, Miss A. M. Bushy Hill, Cambuslang, Lanark.
1883. §Sheild, Robert. Wing House, near Oldham.
1878. ‡Shelford, W., C.E. 35A Great George-street, Westminster, S.W.
1881. ‡Shenstone, W. A. Clifton College, Bristol.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1883. §Shepherd, James. Birkdale, Southport.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1883. §Sherlock, David. Lower Leeson-street, Dublin.

Year of Election.

1883. §Sherlock, Mrs. David. Lower Leeson-street, Dublin.
1883. §Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1880. ‡*Shida, R. 1 St. James's-place, Hillhead, Glasgow.*
1883. §Shillitoe, Buxton. 2 Frederick-place, Old Jewry, London, E.C.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. 4 Varden's-road, Clapham Junction, Surrey, S.W.
1883. §Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, JAMES N., M.Inst.C.E., F.G.S. 3 Westminster-chambers, London, S.W.
1875. ‡Shore, Thomas W., F.C.S., F.G.S. Hartley Institution, Southampton.
1882. ‡Shore, T. W., jun., B.Sc. Uplands, Woolston, Southampton.
1881. §Shuter, James L. Lawn House, Tufnell Park, London, N.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Erlesdene, Bowdon, Cheshire.
1861. *Sidebotham, Joseph. The Beeches, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. The Beeches, Bowdon, Cheshire.
1873. ‡Sidgwick, R. H. The Raikes, Skipton.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1878. ‡Sigerson, Professor George, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1883. §Silby, Miss Agnes. Hook House, Taunton.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1865. ‡*Simkiss, T. M. Wolverhampton.*
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. ‡Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1847. ‡Simon, John, C.B., D.C.L., F.R.S., F.R.C.S., Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. §Simpson, Byrom R. 7 York-road, Birkdale, Southport.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1876. ‡*Simpson, Robert. 14 Ibrox-terrace, Glasgow.*
1883. §Simpson, Walter M. 7 York-road, Birkdale, Southport.
Simpson, William. Bradmore House, Hammersmith, London, W.
1876. ‡*Sinclair, James. Titwood Bank, Pollockshields, near Glasgow.*
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.
1870. *Sinclair, W. P. 19 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, Mahendra Lal, M.D. 51 Sankaritola, Calcutta. (Care of Messrs. S. Harraden & Co., 3 Hill's-place, Oxford-street, London, W.)
1865. ‡Sissons, William. 92 Park-street, Hull.
1879. ‡Skertchly, Sydney B. J., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1883. §Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1870. §SLADEN, WALTER PERCY, F.G.S., F.L.S. Orsett House, Ewell, Surrey.

Year of Election.

1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1873. ‡*Slater, W. B. 42 Clifton Park-avenue, Belfast.*
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.R.M.S. Clifton, Bristol.
1849. ‡Sloper, George Elgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. ‡Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1867. ‡Small, David. Gray House, Dundee.
1881. ‡Smallshan, John. 81 Manchester-road, Southport.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. ‡Smeiton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1876. §Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. 64 Gower-street, London, W.C.
1873. ‡Smith, C. Sidney College, Cambridge.
1865. ‡Smith, David, F.R.A.S. 40 Bennett's-hill, Birmingham.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1876. ‡*Smith, George. Glasgow.*
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1871. *Smith, John Alexander, M.D., F.R.S.E., F.S.A.Scot. 10 Palmerston-place, Edinburgh.
1876. *Smith, J. Guthrie. 173 St. Vincent-street, Glasgow.
1874. ‡Smith, John Haigh. 77 Southbank-road, Southport.
Smith, John Peter George. Sweyney Cliff, near Coalport, Shropshire.
1871. ‡Smith, Professor J. William Robertson. Free Church College, Aberdeen.
1883. §Smith, M. Holroyd. Fern Hill, Halifax.
*Smith, Philip, B.A. The Bays, Parkfields, Putney, S.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §Smith, Robert Angus, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
1840. *Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. §Smithells, Arthur, B. Sc. Owens College, Manchester.
1883. §Smithson, Edward Walter. 13 Lendal, York.

Year of Election.

1883. §Smithson, Mrs. 13 Lendal, York.
1878. ‡Smithson, Joseph S. Balnagowan, Rathmines, Co. Dublin.
1882. §Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S., Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1883. §Smyth, Rev. Christopher. Woodford Rectory, Thrapston.
1874. ‡Smyth, Henry. Downpatrick, Ireland.
1870. ‡*Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.*
1878. §Smyth, Mrs. Isabella. Wigmore Lodge, Cullenswood-avenue, Dublin.
1857. *SMYTH, JOHN, jun., M.A., F.M.S. Milltown, Banbridge, Ireland.
1864. ‡SMYTH, WARINGTON W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 5 Inverness-terrace, Bayswater, London, W.
1854. ‡Smythe, Lieut.-General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1883. §Snape, Joseph. 13 Scarisbrick-street, Southport.
1878. §Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1879. *SOLLAS, W. J., M.A., F.R.S.E., F.G.S., Professor of Geology in Trinity College, Dublin.
*SOLLY, EDWARD, F.R.S., F.L.S., F.G.S., F.S.A. Camden House, Sutton, Surrey.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1883. §Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1863. *Spark, H. King. Starforth House, Barnard Castle.
1879. ‡Spence, David. Brookfield House, Freyinghall, Yorkshire.
1869. *Spence, J. Berger. Erlington House, Manchester.
1881. ‡Spencer, Herbert E. Lord Mayor's Walk, York.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Springbank, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. ‡Spencer, W. H. Richmond Hill, Clifton, Bristol.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1864. *Spottiswoode, W. Hugh. 41 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1883. §Spratling, W. J., B.Sc., F.G.S. Maythorpe, 72 Wickham-road, Brockley, S.E.
1853. †Spratt, Joseph James. West Parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.

Year of Election.

*Squire, Lovell. 9 Osman-road, Hammersmith, London, W.
1879. ‡Stacye, Rev. John. Shrewsbury Hospital, Sheffield.
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1883. *Stanford, Edward, jun., F.R.G.S. 17 Spring-gardens, London, S.W.
1865. ‡STANFORD, EDWARD C. C. Glenwood, Dalmuir, N.B.
1837. Staniforth, Rev. Thomas. Storrs, Windermere.
1881. *Stanley, William Ford. Cumberlow, South Norwood, Surrey, S.E.
1883. §Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1883. §Stapley, Alfred M. Marion-terrace, Crewe.
1866. ‡Starey, Thomas R. Daybrook House, Nottingham.
1876. §Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.
1881. §Stead, W. H. Southport, Lancashire.
1881. §Stead, Mrs. W. H. Southport, Lancashire.
1870. ‡*Stearn, C. H. 2 St. Paul's-villas, Rock Ferry, Liverpool.*
1863. ‡Steele, Rev. Dr. 35 Sydney-buildings, Bath.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1861. ‡Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
1879. *STEPHENSON, HENRY, J.P. Endcliffe Vale, Sheffield.
1881. ‡Stephenson, J. F. 3 Mount-parade, York.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1863. ‡Sterriker, John. Driffield, Yorkshire.
1876. ‡Steuart, Walter. City Bank, Pollockshaws, near Glasgow.
1870. *Stevens, Miss Anna Maria. 13 Elm-place, Bath.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1880. *Stevens, J. Edward. 10 Cleveland-terrace, Swansea.
1868. ‡Stevenson, Henry, F.L S. Newmarket-road, Norwich.
1878. ‡Stevenson, Rev. James, M.A. 21 Garville-avenue, Rathgar, Dublin.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1882. ‡Steward, Rev. C. E., M.A. The Polygon, Southampton.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1875. *Stewart, James, B.A., M.R.C.P.Ed. Dunmurry, Sneyd Park, near Bristol.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1868. ‡*Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.*
1876. ‡Stirling, William, M.D., D.Sc., F.R.S.E., Professor of Physiology in the University of Aberdeen.
1867. *Stirrup, Mark, F.G.S. Richmond Hill, Bowdon, Cheshire.
1865. *Stock, Joseph S. The Grange, Ramsgate.
1883. *STOCKER, W. R. Cooper's Hill, Staines.
1864. ‡STODDART, WILLIAM WALTER, F.G.S., F.C.S. Grafton Lodge, Sneyd Park, Bristol.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
1845. *STOKES, GEORGE GABRIEL, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.

Year of Election.

1874. ‡Stone, J. Harris, B.A., F.L.S., F.C.S. 11 Sheffield-gardens, Kensington, London, W.
1876. ‡Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.
1883. §Stone, Thomas William. 25 Claremont-road, Birkdale, Southport.
1859. ‡Stone, Dr. William H. 14 Dean's-yard, Westminster, S.W.
1857. ‡Stoney, Bindon B., M.Inst.C.E., F.R.S. M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1878. *Stoney, G. Gerald. 9 Palmerston Park, Dublin.
1861. *Stoney, George Johnstone, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 3 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. Kenwyn, Cintra Park, Upper Norwood, S.E.
1883. §Stopes, Mrs. Kenwyn, Cintra Park, Upper Norwood, S.E.
1883. §Stopes, Miss Lucy. 84 East Hill, Colchester.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1873. §Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1859. §Story, Captain James. 17 Bryanston-square, London, W.
1874. §Stott, William. Greetland, near Halifax, Yorkshire.
1871. *Strachey, Lieut.-General Richard, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. Stowey House, Clapham Common, London, S.W.
1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1882. ‡Strange, Rev. Cresswell, M.A. Holy Trinity Vicarage, Southampton.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
Strickland, William. French Park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1883. §Strong, Henry J., M.D. Whitgift House, Croydon.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1876. *Struthers, John, M.D., Professor of Anatomy in the University of Aberdeen.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. Roxeth Lodge, Harrow.
1872. *Stuart, Rev. Edward A., M.A. 116 Grosvenor-road, Highbury New Park, London, N.
1873. ‡Style, Rev. George, M.A. Giggleswick School, Yorkshire.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
1857. ‡Sullivan, William K., Ph.D., M.R.I.A. Queen's College, Cork.
1883. §Summers, Alfred. Sunnyside, Ashton-under-Lyne.
1883. §Summers, William, M.P. Sunnyside, Ashton-under-Lyne.
1883. §Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *Sutherland, George Granville William, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1863. ‡Sutton, Francis, F.C.S. Bank Plain, Norwich.
1881. §Sutton, William. Town Hall, Southport.
1881. ‡Swales, William. Ashville, Holgate-road, York.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1881. §Swan, Joseph W. Mosley-street, Newcastle-on-Tyne.

Year of Election.

1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke, F.R.A.S. Forest Hill Lodge, Warsop, Mansfield, Nottinghamshire.
1879. §Swanwick, Frederick. Whittington, Chesterfield.
1883. §Sweeting, Rev. T. E. 50 Roe-lane, Southport.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburne, Sir John, Bart. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1858. ‡SYDNEY, The Right Rev. ALFRED BARRY, D.D., D.C.L., Bishop of. Sydney.
1883. §Sykes, Alfred. Highfield, Huddersfield.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London, W.
SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. Savilian Professor of Geometry in the University of Oxford. Oxford.
1870. ‡SYMES, RICHARD GLASCOTT, B.A., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
1881. *Symington, Thomas. 13 Dundas-street, Edinburgh.
1856. *Symonds, Frederick, M.A., F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., F.R.S., Sec.R.M.S. 62 Camden-square, London, N.W.
1883. §Symons, Simon. Belfast House, Farquhar-road, Norwood, S.E.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. 7 Great Charles-street, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡TAIT, P. M., F.R.G.S., F.S.S. Oriental Club, Hanover-square, London, W.
1874. §TALMAGE, C. G., F.R.A.S. Leyton Observatory, Essex, E.
1883. §Tapscott, R. L. 41 Parkfield-road, Prince's Park, Liverpool.
1866. ‡Tarbotton, Marrott Ogle, M.Inst.C.E., F.G.S. Newstead-grove, Nottingham.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. 9 Magdala-villas, Margate.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. Longwood, Whitehouse, Belfast.
1863. ‡*Tate, John. Alnmouth, near Alnwick, Northumberland.*
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1876. ‡Tatlock, Robert R. 26 Burnbank-gardens, Glasgow.
1879. ‡Tattershall, William Edward. 15 North Church-street, Sheffield.
1878. *Taylor, A. Claude. Clinton-terrace, Derby-road, Nottingham.

Year of Election.

1874. ‡*Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.*
1867. ‡Taylor, Rev. Andrew. Dundee.
1880. §Taylor, Edmund. Droitwich.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1881. *Taylor, H. A. 112 Cromwell-road, London, S.W.
1882. *Taylor, Herbert Owen, M.D. 17 Castlegate, Nottingham.
1879. ‡Taylor, John. Broomhall-place, Sheffield.
1861. *Taylor, John. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. ‡Taylor, John Ellor, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1883. §Taylor, Michael W., M.D. Hatton Hall, Penrith.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1878. ‡Taylor, Robert, J.P., LL.D. Corballis, Drogheda.
1881. ‡Taylor, Rev. S. B., M.A., Chaplain of Lower Assam, Gauhatti, Assam. (Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.)
1883. §Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. †Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1883. §Taylor, William. Park-road, Southport.
1883. §Taylor, William, M.D. 21 Crockherbtown, Cardiff.
*Taylor, William Edward. Woodlands, Harrow.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1880. ‡Tebb, Miss. 7 Albert-road, Regent's Park, London, N.W.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester.
1876. *Temperley, Ernest., M.A. Queen's College, Cambridge.
1879. ‡Temple, Lieutenant George T., R.N., F.R.G.S. 4 West Pier, London Dock, London, E.
1880. §Temple, Sir Richard, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
1882. §Terrill, William. 3 Hanover-street, Swansea.
1881. ‡Terry, Mr. Alderman. Mount-villas, York.
1883. §Tetley, C. F. The Brewery, Leeds.
1883. §Tetley, Mrs. C. F. The Brewery, Leeds.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, London, W.C.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡Thiselton-Dyer, W. T., M.A., B.Sc., F.R.S., F.L.S. 11 Brunswick-villas, Kew Gardens-road, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1879. *Thomas, Arthur. Endcliffe House, Sheffield.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *Thomas, Christopher James. Drayton Lodge, Redland, Bristol.
1883. §Thomas, Ernest C., B.A. 13 South-square, Gray's Inn, London, W.C.
1883. §Thomas, Miss Fanny. 115 Scotswood-road, Newcastle-on-Tyne.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redlands, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §Thomas, J. Blount. Southampton.

Year of Election.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1880. *Thomas, Joseph William, F.C.S. The Laboratory, West Wharf, Cardiff.
1883. §Thomas, P. Bossley. 4 Bold-street, Southport.
1881. ‡Thomas, Sydney G. 27 Tedworth-square, London, S.W.
1883. §Thomas, T. H. 45 The Walk, Cardiff.
1883. §Thomas, William. Lan, Swansea.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1883. §Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1882. §Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1883. *Thompson, Francis. 1 Avenue-villas, St. Peter's-road, Croydon.
1859. ‡Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
1883. *Thompson, Henry G., M.D. 8 Addiscombe-villas, Croydon.
Thompson, Henry Stafford. Fairfield, near York.
1883. §Thompson, Isaac Cooke. Woodstock, Waverley-road, Liverpool.
1861. *Thompson, Joseph. Riversdale, Wilmslow, Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley Hill.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1876. *Thompson, Richard. Park-street, The Mount, York.
1883. §Thompson, Richard. Branley Mead, Warley, Lancashire.
1874. ‡Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. §THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.A.S., Professor of Physics in University College, Bristol.
1883. *Thompson, T. H. Heald Bank, Bowdon, Manchester.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S. L. & E. 66 Palace Gardens-terrace, Kensington, London, W.
Thomson, Guy. Oxford.
1850. *THOMSON, Professor JAMES, M.A., LL.D., D.Sc., F.R.S.L. & E. 2 Florentine-gardens, Hillhead-street, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 3 Abbotsford-place, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1874. ‡*Thomson, John. Harbour Office, Belfast.*
1883. §Thomson, J. J., M.A. Trinity College, Cambridge.
1871. *THOMSON, JOHN MILLAR, F.C.S. King's College, London, W.C.
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., F.R.A.S., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1877. *Thomson, Lady. The University, Glasgow.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1876. ‡*Thomson, William. 6 Mansfield-place, Edinburgh.*
1880. §Thomson, William J. Ghyllbank, St. Helen's.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thornburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1867. ‡Thornton, Thomas. Dundee.
1883. §Thorowgood, Samuel. Castle-square, Brighton.
1845. ‡Thorp, Dr. Disney. Lyppiatt Lodge, Suffolk Lawn, Cheltenham.
1881. ‡Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.

Year of Election.

1881. *Thorp, Josiah. New Mills, near Huddersfield.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 39 Sandringham-road, Kingsland, London, E.
1871. ‡THORPE, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in Yorkshire College, Leeds.
1883. §Threlfall, Henry. 5 Princes'-street, Southport.
1883. §Thresh, John C., D.Sc. The Willows, Buxton.
1868. ‡THUILLIER, Lieut.-General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. 32 Cambridge-terrace, Hyde Park, London, W.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry and Metallurgy in the Mason Science College, Birmingham. 36 Frederick-road, Birmingham.
1873. ‡Tilghman, B. C. Philadelphia, United States.
1883. §Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. §Tillyard, Mrs. Fordfield, Cambridge.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*TINNE, JOHN A., F.R.G.S. Briarley, Aigburth, Liverpool.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1861. *TODHUNTER, ISAAC, M.A., D.Sc., F.R.S. Brookside, Cambridge.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 7 North-road, Highgate, London, N.
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861. *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1875. §Torr, Charles Hawley. Harrowby House, Park-row, Nottingham.
1863. ‡Torrens, Colonel Sir R. R., K.C.M.G. 12 Chester-place, Hyde Park, London, W.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1883. §Townsend, Francis Edward. 19 Aughton-road, Birkdale, Southport.
1857. *TOWNSEND, Rev. RICHARD, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *TRAIL, Professor J. W. H., M.A., M.D., F.L.S. University of Aberdeen, Old Aberdeen.
1883. §Traill, Dr. Ballylough, Bushmills, Ireland.
1870. ‡TRAILL, WILLIAM A., M.R.I.A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1883. §Traill, Mrs. Portrush, Ireland.
1875. ‡Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡TRAQUAIR, RAMSAY H., M.D., F.R.S., Professor of Zoology. Museum of Science and Art, Edinburgh.

Year of Election.

1865. ‡*Travers, William, F.R.C.S.* 1 *Bath-place, Kensington, London, W.*
Tregelles, Nathaniel. Liskeard, Cornwall.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1883. §Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1871. ‡TRIBE, ALFRED, F.C.S. 14 Denbigh-road, Bayswater, London, W.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡TRIMEN, HENRY, M.B., F.L.S. British Museum, London, S.W.
1871. ‡TRIMEN, ROWLAND, F.R.S., F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §TRISTRAM, Rev. HENRY BAKER, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1882. *Trotter, Rev. Coutts, M.A. Trinity College, Cambridge.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1881. §Tully, G. T. 10 West Cliff-terrace, Preston.
1883. §TUPPER, Sir CHARLES, K.C.M.G., High Commissioner for Canada. 9 Victoria-chambers, London, S.W.
1854. ‡TURNBULL, JAMES, M.D. 86 Rodney-street, Liverpool.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill-villas, Cheltenham.
1871. ‡Turnbull, William, F.R.S.E. Menslaws, Jedburgh, N.B.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
1882. §Turner, G. S. 9 Carlton-crescent, Southampton.
1883. §Turner, Mrs. G. S. 9 Carlton-crescent, Southampton.
1875. ‡Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.
1863. *TURNER, WILLIAM, M.B., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1883. §Turrell, Miss S. S. High School, Redland-grove, Bristol.
1842. Twamley, Charles, F.G.S. Ryton-on-Dunsmore, Coventry.
1847. ‡TWISS, Sir TRAVERS, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1882. §Tyer, Edward. Horneck, Fitzjohn's-avenue, Hampstead, London, N.W.
1865. ‡TYLOR, EDWARD BURNETT, D.C.L., F.R.S., Keeper of the University Museum, Oxford.
1858. *TYNDALL, JOHN, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1883. §Tyrer, Thomas, F.C.S. Battersea, London, S.W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1883. §Unwin, John, Park-crescent, Southport.
1883. §Unwin, William. The Briars, Freshfield, near Liverpool.
1876. *UNWIN, W. C., M.Inst.C.E., Professor of Hydraulic Engineering. Cooper's Hill, Middlesex.
1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.

Year of Election.

1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1883. *VanSittart, Mrs. R. F. A. 11 Lypiatt-terrace, Cheltenham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. 2 Hamilton-road, Highbury Park, London, N.
1870. ‡Varley, Mrs. S. A. 2 Hamilton-road, Highbury Park, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. §Vaughan, William. 42 Sussex-road, Southport.
1846. ‡Vaux, W. S. W., M.A., F.R.S. 22 Albemarle-street, London, W.
1881. §VELEY, V. H., B.A., F.C.S. University College, Oxford.
1873. *VERNEY, Captain EDMUND H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.
1883. *Verney, Mrs. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
Vernon, George John, Lord. Sudbury Hall, Derbyshire.
1883. §VERNON, H. H., M.D. York-road, Birkdale, Southport.
1879. ‡Veth, D. D. Leiden, Holland.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1875. ‡Vines, David, F.R.A.S. Observatory House, Somerset-street, Kingsdown, Bristol.
1883. §Vines, Sydney Howard. Christ's College, Cambridge.
1856. ‡VIVIAN, EDWARD, M.A. Woodfield, Torquay.
*VIVIAN, Sir H. HUSSEY, Bart., M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1856. §VOELCKER, J. CH. AUGUSTUS, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
1869. ‡Vose, Dr. James. Gambier-terrace, Liverpool.

1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1879. *Wake, Bernard. Abbeyfield, Sheffield.
1870. §WAKE, CHARLES STANILAND. 2 Westbourne-avenue, Hull.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.
1869. *Walford, Cornelius. 86 Belsize Park-gardens, London, N.W.
1882. *Walkden, Samuel. Care of Louis de Souza, Esq., 1 Hare-court, Temple, London, E.C.
1883. §Walker, E. R. Pagefield Ironworks, Wigan.
Walker, Frederick John. The Priory, Bathwick, Bath.
1883. §Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1855. ‡*Walker, John. 1 Exchange-court, Glasgow.*
1866. *WALKER, JOHN FRANCIS, M.A., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1881. ‡Walker, John Sydenham. 83 Bootham, York.
1883. §Walker, Mrs. 14 Bootham-terrace, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1883. §Walker, Thomas A. 4 Saunders-street, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1881. *Walker, William. 14 Bootham-terrace, York.

Year of
Election.

1883. §Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, F.L.S., F.R.G.S. Nutwood Cottage, Frith Hill, Godalming.
1883. §Wallace, George F. Hawthornbank, Dunfermline.
1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 138 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡Wallich, George Charles, M.D., F.L.S., F.R.G.S., 3 Christchurch-road, Roupell Park, London, S.W.
1883. §Wallis, Rev. Frederick. Caius College, Cambridge.
1883. §Walmesley, Oswald. Shevington Hall, near Wigan.
1883. §Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
1881. §Walton, Thomas. Oliver's Mount School, Scarborough.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1872. ‡Warburton, Benjamin. Leicester.
1874. §Ward, F. D., J.P., M.R.I.A. Clonaver, Strandtown, Co. Down.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡Ward, H. Marshall. Christ's College, Cambridge.
1874. §Ward, John, F.S.A., F.G.S., F.R.G.S. Lenoxvale, Belfast.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. 41 Head-street, Colchester.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
1883. §Ward, Thomas, F.C.S. Arnold House, Blackpool.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida Vale, London, W.
1878. §WARINGTON, ROBERT, F.C.S. Harpenden, St. Albans, Herts.
1882. ‡Warner, F. W., F.L.S. 20 Hyde-street, Winchester.
1856. ‡*Warner, Thomas H. Lee. Tiberton Court, Hereford.*
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1883. *Warren, Dr. Samuel. Abberley Villa, Hoylake.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1876. ‡Waterhouse, A. Willenhall House, Barnet, Herts.
1875. *Waterhouse, Major J. 1 Wood-street, Calcutta. (Care of Messrs. Trübner & Co., Ludgate-hill, London, E.C.)
1854. ‡Waterhouse, Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875. ‡Waters, Arthur W., F.G.S., F.L.S. Woodbrook, Alderley Edge, near Manchester.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1883. §Watson, C. Knight, M.A. Society of Antiquaries, Burlington House, London, W.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 1 Woodside-terrace, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorne House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.

Year of Election.

1882. §Watson, Rev. H. W., M.A., F.R.S. Berkswell Rectory, Coventry.
1873. *Watson, Sir James. Milton-Lockhart, Carluke, N.B.
1859. ‡Watson, John Forbes, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 41 Cross-street, Finsbury, London, E.C.
1879. *Watson, William Henry, F.C.S., F.G.S. Analytical Laboratory, The Folds, Bolton-le-Moors.
1882. §Watt, Alexander. 89 Hartington-road, Sefton Park, Liverpool.
1869. ‡Watt, Robert B. E., F.R.G.S. Ashley-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1875. *Watts, John, B.A., D.Sc. Merton College, Oxford.
1846. ‡Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *Watts, W. Marshall, D.Sc. Giggleswick Grammar School, near Settle.
1883. §Watts, W. W. Broseley, Shropshire.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
1859. *Waveney, The Right Hon. Lord, F.R.S. 7 Audley-square, London, W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. §Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
*Webb, Rev. Thomas William, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.
1866. *Webb, William Frederick, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1882. *Webster, Richard Everard, Q.C. 2 Pump-court, Temple, London, E.C.
1854. ‡Weightman, William Henry. Fern Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.
1867. §Weldon, Walter, F.R.S. L.& E., F.C.S. Rede Hall, Burstow, near Crawley, Surrey.
1876. §Weldon, W. F. R. St. John's College, Cambridge.
1881. §Wellcome, Henry S. 111 Marylebone-road, London, N.W.
1879. §Wells, Charles A. Lewes; and Manor House, Seaford.
1881. §Wells, Rev. Edward, B.A. Flamstead Vicarage, Dunstable.
1883. §Wells, G. I. J. Cressington Park, Liverpool.
1883. §Welsh, Miss. Girton College, Cambridge.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. 8 Great Cumberland-place, London, W.; and Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.

Year of Election.

1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1870. *Westgarth, William. 10 Bolton-gardens, South Kensington, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
1882. §Westlake, Ernest, F.G.S. Fordingbridge, Hants.
1882. ‡Westlake Richard. Portswood, Southampton.
1857. *Westley, William. 24 Regent-street, London, S.W.
1882. §Westlake, W. C. Grosvenor House, Southampton.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1875. *Weston, Joseph D. Dorset House, Clifton Down, Bristol.
1864. ‡WESTROPP, W. H. S., M.R.I.A. Lisdoonvarna, Co. Clare.
1860. ‡WESTWOOD, JOHN O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1882. §WETHERED, EDWARD, F.G.S. 5 Berkeley-place, Cheltenham.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1883. *Wheeler, George Brash. 11 Queen Victoria-street, London, E.C.
1878. *Wheeler, W. H., M.Inst.C.E. Boston, Lincolnshire.
1883. §Whelpton, Miss K. Newnham College, Cambridge.
1879. *Whidborne, Rev. George Ferris, M.A., F.G.S. Charante, Torquay.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1874. ‡Whitaker, Henry, M.D. 33 High-street, Belfast.
1859. *WHITAKER, WILLIAM, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1876. ‡White, Angus. Easdale, Argyleshire.
1883. §White, Charles. 23 Alexandra-road, Southport.
1864. ‡*White, Edmund. Victoria Villa, Batheaston, Bath.*
1882. §White, Rev. George Cecil, M.A. St. Paul's Vicarage, Southampton.
1876. *White, James. Overtoun, Dumbarton.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡WHITE, JOHN FORBES. 16 Bon Accord-square, Aberdeen.
1883. §White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blandford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 365 Euston-road, London, N.W.
1883. *White, Mrs. 365 Euston-road, London, N.W.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Drood House, Old Trafford, Manchester.
1883. §Whitehead, P. J. 6 Cross-street, Southport.
1855. *Whitehouse, Wildeman W. O. Science Club, Savile-row, London, W.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1881. §Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1866. ‡Whitfield, Samuel. Eversfield, Eastnor-grove, Leamington.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.

Year of
Election.

1883. §Whittaker, T. 13 Albert-road, Southport.
1870. ‡Whittem, James Sibley. Walgrave, near Coventry.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 4 Roderick-road, London, N.W.
1874. *Whitwell, Mark. Redland House, Bristol.
1883. §Whitworth, James. 88 Portland-street, Southport.
*WHITWORTH, Sir JOSEPH, Bart., LL.D., D.C.L., F.R.S. Stancliffe, Matlock, Derbyshire.
1870. ‡WHITWORTH, Rev. W. ALLEN, M.A. Glenthorne-road, Hammersmith, London, W.
1865. ‡Wiggin, Henry. Metchley Grange, Harborne, Birmingham.
1881. *Wigglesworth, James. Market-street, Wakefield.
1883. §Wigglesworth, Mrs. Market-street, Wakefield.
1881. *Wigglesworth, Robert. Buckingham Works, York.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1883. §Wigner, G. W., F.C.S. Plough-court, 37 Lombard-street, London, E.C.
1881. ‡WILBERFORCE, W. W. Fishergate, York.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1879. ‡Wilkinson, Joseph. York.
1859. ‡WILKINSON, ROBERT. Lincoln Lodge, Totteridge, Hertfordshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
*Willert, Alderman Paul Ferdinand. Town Hall, Manchester.
1859. ‡Willet, John, M.Inst.C.E. 35 Albyn-place, Aberdeen.
1872. ‡WILLETT, HENRY, F.G.S. Arnold House, Brighton.
WILLIAMS, CHARLES JAMES B., M.D., F.R.S. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 47 Upper Brook-street, Grosvenor-square, London, W.
1883. *Williams, Edward Starbuck. Ty-as-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 1 Gorse-lane, Swansea.
1875. *Williams, Herbert A., M.A. 91 Pembroke-road, Clifton, Bristol.
1883. §Williams, Rev. H. A. 55 Bath-street, Southport.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1870. §WILLIAMS, JOHN, F.C.S. 14 Buckingham-street, London, W.C.
1875. *Williams, M. B. North Hill, Swansea.
1879. ‡WILLIAMS, MATTHEW W., F.C.S. Sterndale House, Sterndale-road, Brook Green, London, W.
Williams, Robert, M.A. Bridehead, Dorset.
1883. §Williams, R. Price. North Brow, Primrose Hill, London, N.W.
1869. ‡WILLIAMS, Rev. STEPHEN. Stonyhurst College, Whalley, Blackburn.
1883. §Williams, T. H. 2 Chapel-walk, South Castle-street, Liverpool.
1883. §Williams, T. Rowell. 125 Fortess-road, London, N.W.
1877. *Williams, W. Carleton, F.C.S. Firth College, Sheffield.
1865. ‡*Williams, W. M. Belmont-road, Twickenham, near London.*
1883. §Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., For. Sec. R.S., F.C.S., Corresponding Member of the French Academy, Professor of Chemistry, and of Practical Chemistry, University College, London. (GENERAL TREASURER.) University College, London, W.C.
1857. ‡Williamson, Benjamin, M.A., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1876. ‡Williamson, Stephen. 19 James-street, Liverpool.

Year of Election.

WILLIAMSON, WILLIAM C., LL.D., F.R.S., Professor of Natural History in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1883. §WILLIS, T. W. 51 Stanley-street, Southport.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1859. *Wills, Alfred, Q.C. 12 King's Bench-walk, Inner Temple, London, E.C.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. 124 Bothwell-street, Glasgow.
1859. ‡Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. ‡WILSON, Lieut.-Colonel Sir C. W., R.E., C.B., D.C.L., F.R.S., F.R.G.S., Director of the Topographical and Statistical Department of the War Office. 5 Lansdowne-terrace, Rodwell, Weymouth.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1875. ‡Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1883. *Wilson, Henry, M.A. Eastnor, Malvern Link, Worcestershire.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1855. ‡Wilson, Hugh. 75 Glasford-street, Glasgow.
1857. ‡Wilson, James Moncrieff. Queen Insurance Company, Liverpool.
1865. ‡WILSON, Rev. JAMES M., M.A., F.G.S. The College, Clifton, Bristol.
1858. *Wilson, John. Seacroft Hall, near Leeds.
WILSON, JOHN, F.R.S.E., F.G.S., Professor of Agriculture in the University of Edinburgh. The University, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. §Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S., Assistant Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1854. *Winfield, Edward Higgin. Edelstowe, Bromley Park, Bromley, Kent.
1868. ‡*Winter, C. J. W. 22 Bethel-street, Norwich.*
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1883. §Wolfenden, Samuel. Cowley Hill, St. Helen's, Lancashire.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Bridge of Earn, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. §Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
*Wood, George B., M.D. 1117 Arch-street, Philadelphia, United States.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. §WOOD, H. TRUEMAN, B.A. Society of Arts, John-street, Adelphi, London, W.C.

Year of Election.

1883. *Wood, James, LL.D. Woodbank, Mornington-road, Southport.
1881. §Wood, John, B.A., F.R.A.S. Wharfedale Cottage, Boston Spa, Yorkshire.
1883. *Wood, J. H. Woodbine Lodge, Scarisbrick New-road, Southport.
1883. §Wood, Mrs. Mary. Ellison-place, Newcastle-on-Tyne.
1883. §Wood, P. F. Ardwick Lodge, Park-avenue, Southport.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, Provost T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
Wood, William. Edge-lane, Liverpool.
1865. *Wood, William, M.D. 99 Harley-street, London, W.
1861. ‡Wood, William Rayner. Singleton Lodge, near Manchester.
1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *Woodall, Major John Woodall, M.A., F.G.S. St. Nicholas House, Scarborough.
1870. ‡Woodburn, Thomas. Rock Ferry, Liverpool.
1883. §Woodcock, Herbert S. The Elms, Wigan.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1865. ‡Woodhill, J. C. Pakenham House, Charlotte-road, Edgbaston, Birmingham.
1871. †Woodiwis, James. 51 Back George-street, Manchester.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. ‡Woodman, William Robert, M.D. Ford House, Exeter.
*Woods, Edward, M.Inst.C.E. 6b Victoria-street, Westminster, London, S.W.
1883. §Woods, Dr. G. A., F.R.M.S. Carlton House, 57 Hoghton-street, Southport.
Woods, Samuel. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
*Woodward, C. J., B.Sc. 97 Harborne-road, Birmingham.
1866. ‡Woodward, Henry, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1881. §Wooler, W. A. Sadberge Hall, Darlington.
1877. ‡Woollcombe, Robert W. 14 Acre-place, Stoke, Devonport.
1883. **Woolley, George Stephen.*
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1872. ‡Woolmer, Shirley. 6 Park-crescent, Brighton.
Worcester, The Right Rev. Henry Philpott, D.D., Lord Bishop of. Hartlebury Castle, Kidderminster.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. §Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Stourbridge, Worcestershire.
Worthington, Archibald. Whitchurch, Salop.
Worthington, James. Sale Hall, Ashton-on-Mersey.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1879. §Wrentmore, Francis. 34 Holland Villas-road, Kensington, London, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.

Year of Election.

1883. §Wright, Rev. Benjamin. The Rectory, Darlaston.
1871. §WRIGHT, C. R. A., D.Sc., F.R.S., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1876. ‡Wright, James. 114 John-street, Glasgow.
1874. ‡Wright, Joseph. Cliftonville, Belfast.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
*Wright, Robert Francis. Hinton Blewett, Temple-Cloud, near Bristol.
1855. ‡WRIGHT, THOMAS, M.D., F.R.S. L. & E., F.G.S. St. Margaret's-terrace, Cheltenham.
WRIGHT, T. G., M.D. Milnes House, Wakefield.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡Wrightson, Thomas. Norton Hall, Stockton-on-Tees.
1867. ‡WÜNSCH, EDWARD ALFRED. 146 West George-street, Glasgow.
Wyld, James, F.R.G.S. Charing Cross, London, W.C.
1863. *Wyley, Andrew. Clifford Cottage, Besley, Redditch.
1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.
1883. §Wyllie, Andrew. 10 Park-road, Southport.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S., of the Geological Survey of India. Bombay.

1875. ‡Yabbicom, Thomas Henry, C.E. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
Yates, James. Carr House, Rotherham, Yorkshire.
1883. §Yates, James. Public Library, Leeds.
1867. ‡Yeaman, James. Dundee.
1879. ‡Yeomans, John. Upperthorpe, Sheffield.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1879. *YORK, His Grace the Archbishop of, D.D., F.R.S. The Palace, Bishopsthorpe, Yorkshire.
1876. *Young, James, F.C.S. Kelly, Wemyss Bay, by Greenock.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1883. *Young, Sydney. University College, Bristol.
1868. ‡Youngs, John. Richmond Hill, Norwich.
1876. ‡Yuille, Andrew. 7 Sardinia-terrace, Hillhead, Glasgow.
1871. †YULE, Colonel HENRY, C.B., F.R.G.S. 3 Penywern-road, South Kensington, London, S.W.

CORRESPONDING MEMBERS.

Year of
Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia.
1882. Dr. E. H. von Baumhauer, Professor of Chemistry. The University, Harlem.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1880. Professor Ludwig Boltzmann. Halbärtgasse, 1, Gräz, Austria.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological Institute of the Netherlands. Utrecht, Holland.
1861. Dr. Carus. Leipzig.
1882. Dr. R. Clausius, Professor of Physics. The University, Bonn.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1871. Professor Dr. Colding. Copenhagen.
1881. Professor Josiah P. Cooke. Harvard University, United States.
1873. Signor Guido Cora. 17 Via Providenza, Turin.
1880. Professor Cornu. L'École Polytechnique, Paris.
1870. J. M. Crafts, M.D. École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome.
1872. *Professor M. Croullebois. 18 Rue Sorbonne, Paris.*
1866. Dr. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1864. M. Des Cloizeaux. Paris.
1872. Professor G. Devalque. Liége, Belgium.
1870. Dr. Anton Dohrn. Naples.
1882. Professor Dumas. L'Institut, Paris.
1882. Dr. Emil Du Bois-Reymond, Professor of Physiology. The University, Berlin.
1881. Captain J. B. Eads, M.Inst.C.E. St. Louis, United States.
1876. Professor Alberto Eccher. Florence.
1861. Professor A. Favre. Geneva.
1874. Dr. W. Feddersen. Leipzig.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1856. Professor E. Frémy. L'Institut, Paris.
1842. *M. Frisiani.*
1881. C. M. Gariel, Secretary of the French Association for the Advancement of Science, Paris.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1870. Governor Gilpin. Colorado, United States.
1876. Dr. Benjamin A. Gould, Director of the Argentine National Observatory, Cordoba.
1852. Professor Asa Gray. Harvard University, United States.
1871. Dr. Paul Güssfeldt, of the University of Bonn. 33 Meckenheimerstrasse, Bonn, Prussia.

Year of Election.

1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. Baltimore, United States.
1872. Professor James Hall. Albany, State of New York.
1881. M. Halphen. 21 Rue Ste. Anne, Paris.
1864. M. Hébert, Professor of Geology in the Sorbonne, Paris.
1877. Professor H. L. F. Helmholtz. Berlin.
1868. A. Heynsius. Leiden.
1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington.
1861. Dr. Hochstetter. Vienna.
1881. Dr. A. A. W. Hubrecht. Leiden.
1876. Professor von Quintus Icilius. Hanover.
1867. Dr. Janssen, LL.D. 21 Rue Labat (18° Arrondissement), Paris.
1876. Dr. W. J. Janssen. The University, Leiden.
1862. Charles Jessen, Med. et Phil. Dr. Kastanienallee, 69, Berlin.
1881. Professor W. Woolsey Johnson. Annapolis, United States.
1876. Dr. Giuseppe Jung. 9 Via Monte Pietà, Milan.
1877. M. Akin Kàroly. 5 Babenbergerstrasse, Vienna.
1862. Aug. Kekulé, Professor of Chemistry. Bonn.
1873. *Dr. Felix Klein. Munich, Bavaria.*
1874. Dr. Knoblauch. Halle, Germany.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
Laurent-Guillaume De Koninck, M.D., Professor of Chemistry and Palæontology in the University of Liége, Belgium.
1877. Dr. Hugo Kronecker, Professor of Physiology. 35 Dorotheenstrasse, Berlin.
1882. Professor S. P. Langley. Allegheny, United States.
1876. Professor von Lasaulx. Breslau.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
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